DOCUMENT RESUME

ED 185 333 CE 024 798

TITLE	Fuels, Lubricants, and Coolants. FOS: Fundamentals of Service.
INSTITUTION	John Deere Co., Moline, Ill.
PUB DATE	79
NOTE	71p.; For related documents see CE 024 540-546, CE 024 797 and CE 025 209-214.
AVAILABLE FROM	John Deere Distribution Service Center, Service Publications, Dept. 333, 1400-3rd Ave., Moline, IL 61265 (Order No. FOS-5803B, $4.25; 10 or more--$3.19 each; supplementary slide set--$24.00)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Agricultural Education; Agricultural Engineering; Agricultural Machinery; Equipment Maintenance; *Fuels; Instructional Materials; *Lubricants; Postsecondary Education; *Power Technology; Secondary Education; Tractors; *Vocational Education
IDENTIFIERS	*Coolants

ABSTRACT

This manual on fuels, lubricants, and coolants is one of a series of power mechanics tests and visual aids on automotive and off-the-road agricultural and construction equipment. Materials present basic information with illustrations for use by vocational students and teachers as well as shop servicemen and laymen. Focusing on fuels, the first of three parts discusses areas such as compression and fuels, octane ratings, selecting fuels for liquid propane gas engines, diesel fuel characteristics, and storing fuels. Part 2, Lubricants, describes engine oils, engine oil ratings, contamination of oil, mistaken ideas about engine oils, storing and handling engine oils, and hydraulic and transmission fluids. Part 3 focuses on coolants and discusses topics such as parts of the liquid cooling system, water as a coolant, warm weather conditioning of the system, preventing corrosion and deposits, and water pump and fan lubrication. Each part concludes with test questions. Answers to the test questions are appended. (A supplementary 35mm color slide set is also available--see availability note.) (LRA)

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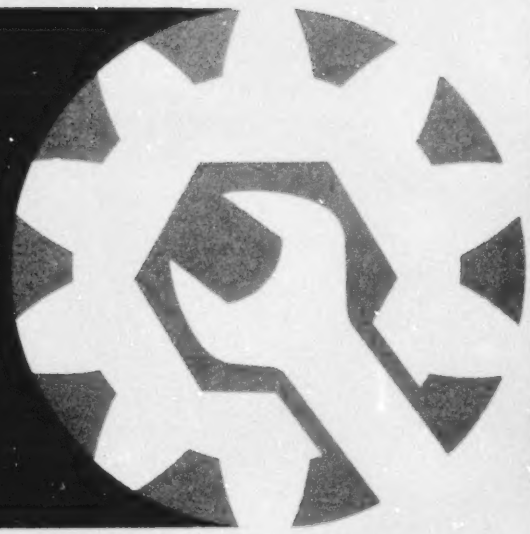
Fuels, Lubricants and Coolants

JOHN DEERE

FOS

FUNDAMENTALS OF SERVICE



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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

TO THE READER

PURPOSE OF THIS MANUAL

The main purpose of this manual is to give you the hows and whys of modern fuels, lubricants, and coolants. For the novice, it is a training guide; for the journeyman, a reference. The story is written in simple form using many illustrations so that it can be easily understood.
Metric equivalents (shown in parentheses) have been added in this edition.

WHAT IS "FUNDAMENTALS OF SERVICE"?

This manual is part of a series of texts and visuals called "Fundamentals of Service", or "FOS". These materials are basic information in power mechanics for use by teachers as well as shop servicemen and the layman. All types of modern equipment are covered — both automotive and off-the-road. Emphasis is on theory of operation, diagnosis, and repair.

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ACKNOWLEDGEMENTS
John Deere gratefully acknowledges help from the following groups: American Association for Agricultural Engineering and Vocational Agriculture; American Petroleum Institute; American Society of Agricultural Engineers (ASAE); Borg-Warner Corp.; Dana Corp.; Ethyl Corp.; Federal-Mogul Corp.; Gulf Oil Corp.; Imperial Oil Ltd.; National Board of Fire Underwriters; National Fire Protection Assoc.; National LP-Gas Assoc.; Purdue University Extension Service; Shell Oil Co.; Society of Automotive Engineers; Standard Oil Company; Texaco, Inc.; TRW Replacement Div.; Union Carbide Corp.; University of Missouri Experiment Station.

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FOS — 58 Litho in U.S.A.

CONTENTS

Part 1 — FUELS

Introduction 1
Compression and Fuels 2
Selecting Fuel for Gasoline Engines 4
Octane Ratings 4
Gasoline Additives 6
Selecting Fuels for LP-Gas Engines 9
Selecting Fuels for Diesel Engines 10
Diesel Fuel Characteristics 12
Storing Gasoline Fuels 16
Storing Diesel Fuels 21
Storing LP-Gas Fuels 24
Test Yourself 25

Part 2 — LUBRICANTS

Introduction 27
Engine Oils 28
Producing Oils 29
Engine Oil Ratings 30
SAE Viscosity 31
API Service Ratings 32
U.S. Army and Engine Maker's Ratings 35
Contamination of Oil 37
Oil Additives 41
Mistaken Ideas About Engine Oils 41
Special Oils for Off-the-Road Engines 43
Summary: Selecting Engine Oils 44
Storing And Handling Engine Oils 45
Gear Oils 46
Hydraulic and Transmission Fluids 49
Lubricating Greases 53
Test Yourself 54

Part 3 — COOLANTS

Introduction 55
Parts of Liquid Cooling System 56
Development of Liquid Cooling 56
Water as a Coolant 57
Antifreezes 57
Warm Weather Conditioning of System 62
Preventing Leaks 62
Preventing Corrosion and Deposits 65
Flushing and Cleaning the System 65
Water Pump and Fan Lubrication 66
Stopping a Hot Engine 66
Summary: Coolants 66
Test Yourself 67

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FUELS / PART 1

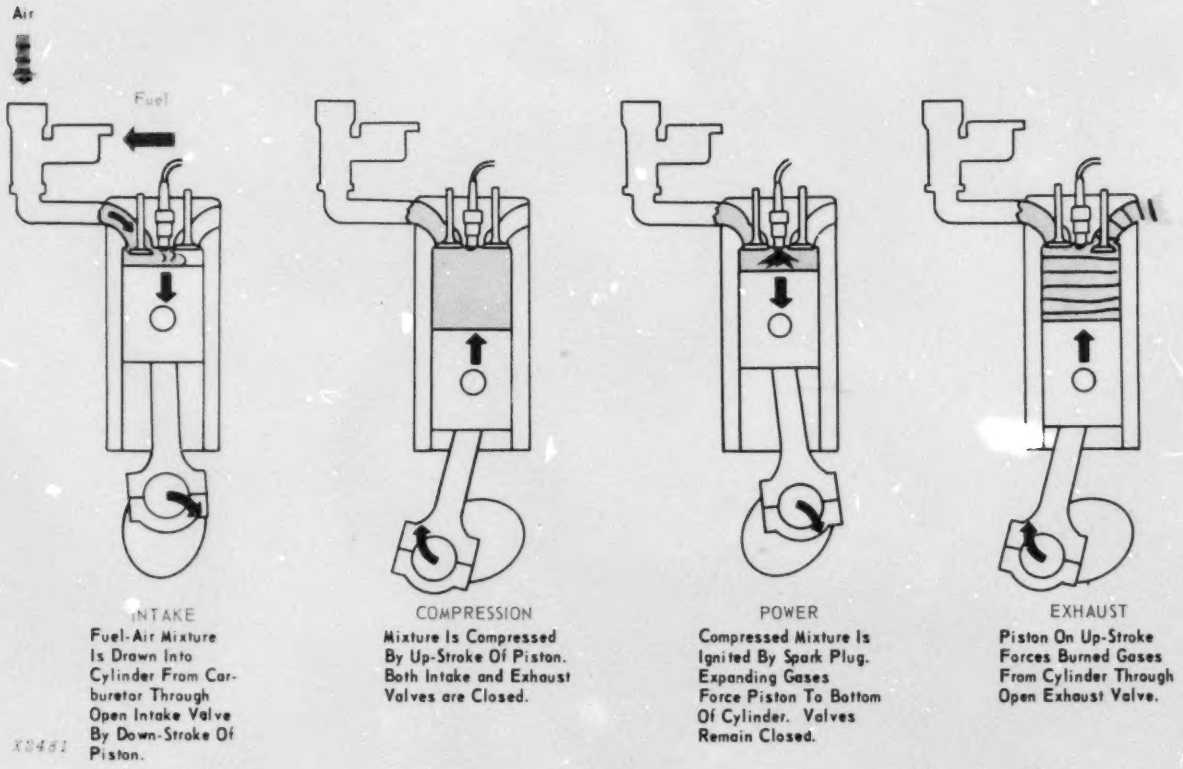

Air
Fuel
INTAKE
Fuel-Air Mixture Is Drawn Into Cylinder From Carburetor Through Open Intake Valve By Down-Stroke Of Piston.
COMPRESSION
Mixture Is Compressed By Up-Stroke Of Piston. Both Intake and Exhaust Valves are Closed.
POWER
Compressed Mixture Is Ignited By Spark Plug. Expanding Gases Force Piston To Bottom Of Cylinder. Valves Remain Closed.
EXHAUST
Piston On Up-Stroke Forces Burned Gases From Cylinder Through Open Exhaust Valve.
X9461

Fig. 1 — How A Four-Stroke Cycle Engine Works (Gasoline Shown)

INTRODUCTION

If you purchase a new machine today, you will find it is designed for use with a certain fuel. For example, if it is a diesel tractor, you have no choice but to use diesel fuel. It will not operate on gasoline or LP-Gas.

This situation has not always been true. Two-fuel tractors that started on gasoline and operated on kerosene or distillate were quite popular at one time. Some are still in use but they are not as efficient as tractors designed for use with one fuel. Today they are being replaced with the one-fuel type.

From this it might appear that there is no fuel selection problem once you have selected your machine. But the quality of each fuel you use is directly related to the maintenance required and to the performance you can expect to get.

Then, too, the quality of fuels and their ingredients keep changing. Various terms are used to describe these changes, such as: "octane rating," "sulfur content," "cetane rating" and "volatility." You need to know what these terms mean in order to understand what these changes mean as they apply to your machine. An example is the gradual increase in the octane rating of regular gasoline over a period of years. Is it of any real value to you as a user of a gasoline machine?

In addition, spark-ignition (carburetor) engines require fuels with certain qualities, while diesel engines require other fuel qualities. This is because of the difference in the way the fuel is ignited in each type.

If you are not familiar with the two types of engines and how they work, study Figures 1 and 2. They show the operating principles of engines now being used on farm and industrial machines.

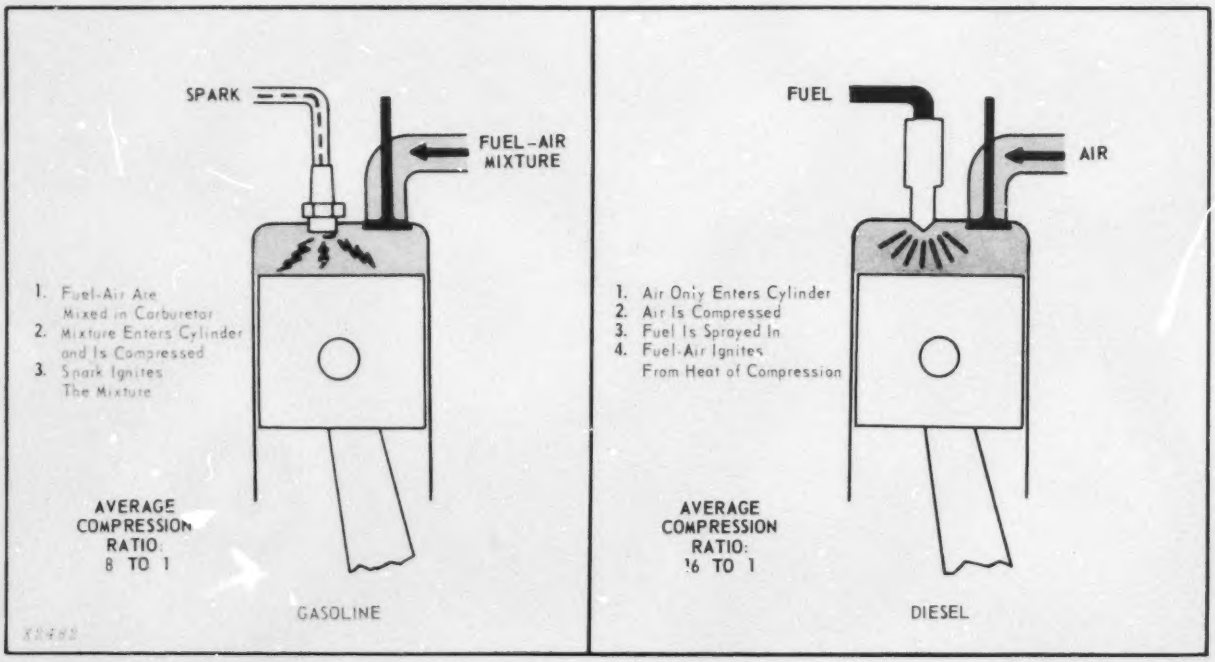


Fig. 2 — Gasoline And Diesel Engines Compared

The important points you need to know about selection of each fuel are discussed under these headings:

1. **Selecting fuel for gasoline engines**
2. **Selecting fuel for LP-Gas engines**
3. **Selecting fuel for diesel engines**

COMPRESSION AND FUELS

In discussing each of these fuels, the term "compression ratio" is used frequently. It is important that you understand its meaning.

Compression ratio is the relation between the total volume inside the engine cylinder when the piston is at its greatest distance from the cylinder head (Fig. 3), compared to the volume when the piston has traveled closest to the cylinder head.

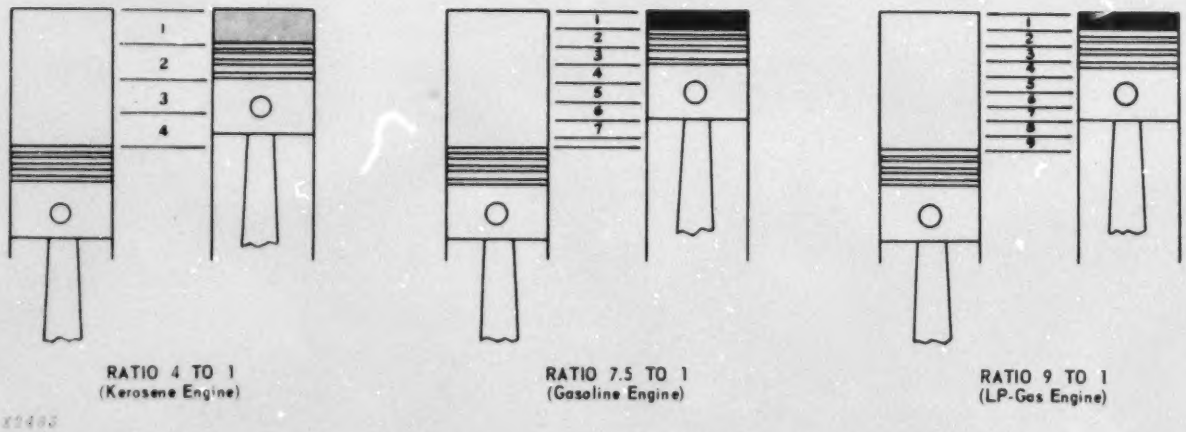
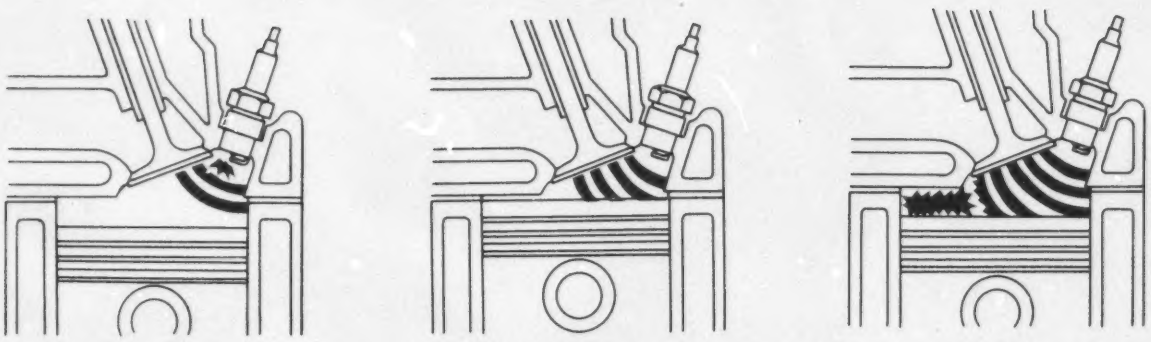


Fig. 3 — Fuels Must Be Matched With Engines Of Proper Compression Ratios



1. Spark Begins Fuel-Air Mixture Burning.

2. Flame Advances Smoothly, Compressing and Heating End-Charge.

3. End-Charge Suddenly Ignites With Violence, Producing A Knock.

X 1877

Fig. 4 — How Combustion Knock Occurs In A Gasoline Engine

When heavier fuels, such as kerosene or distillate, are used in a spark-ignition engine, this ratio must be low for satisfactory operation — approximately 4 to 1 (Fig. 3).

With lighter fuels such as regular gasoline, the compression ratio can be increased to about 7 to 1 and as high as 8.5 to 1.

LP-Gas, a still lighter fuel, can have a compression ratio of 8.5 to 1 or higher.

The higher the compression ratio, the more the fuel-air mixture is compressed and the higher the pressure inside the cylinder before the fuel burns. If the fuel burns properly, higher compression greatly increases the power output of the engine because more of the fuel energy is developed into useful power.

However, each fuel has its limits on how much it can be compressed and still burn properly when ignited in a spark-ignition engine.

For example, kerosene burns evenly in an engine with a compression ratio of 4 to 1 (Fig. 3) and supplies a smooth flow of power. But if it is used in an engine with a compression ratio of 7.5 to 1, it will burn unevenly and cause the engine to "*knock*" (Fig. 4). During knock, fuel ignites next to the spark plug and builds up tremendous pressure on the unburned fuel as shown. This pressure then causes spontaneous combustion of the unburned fuel, causing a small explosion or knock.

Fuel knock is a serious problem because it is hard on valves, pistons (Fig. 5) and bearings and results in a loss of power.

If regular gasoline is used in place of kerosene, it will burn satisfactorily with either the 4 to 1 compression ratio or the 7 to 1 compression ratio. However it will not burn satisfactorily in an engine with a 9 to 1 compression ratio.

X 1878

Fig. 5 — Combustion Knock Damaged This Piston And Broke The Top Ring

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COMPRESSION RATIOS AND OCTANE RATINGS OF SPARK-IGNITION FUELS

Fuel	Engine Compression Ratio (approx).	Approx. Octane No.
*Kerosene, No. 1 fuel oil**	4.0 to 1	0- 30 (Motor Method)
*"Farm Tractor Fuel"***	4.7 to 1	45- 70 (Motor Method)
Gasoline (low grade)	5.0- 6.0 to 1	70- 75 (Research Method)
Gasoline (regular)	7.0- 8.5 to 1	88- 94 (Research Method)
*Gasoline (premium)****	9.0-10.0 to 1	About 100 (Research Method)
LP-Gas: Butane	7.8 to 1	95-100 (Research Method)
Propane	8.75 to 1	110-115 (Research Method)

**Well adapted to magneto ignition because of longer spark duration.*

***Standard name used in place of a number of other terms such as: distillate or power fuel.*

****Not normally used in farm and industrial machines.*

The table above gives the compression ratios and octane ratings expected with modern fuels. With diesel fuels, *cetane* ratings are a prime factor in performance, and this will be covered later.

SELECTING FUEL FOR GASOLINE ENGINES

Gasoline is a widely used fuel for farm and industrial machines. This has not always been true because at one time gasoline could not compete with other fuels in price and the supply was somewhat limited. The supply situation has changed as oil companies have found ways of increasing the amount of gasoline they can get from a barrel of crude oil.

Another factor that helped make gasoline a popular fuel was the raising of the "octane rating." Machines with higher compression ratios were then developed to take advantage of the efficiency made possible by using the higher octane fuels.

Almost all one-fuel gasoline machines are designed to operate on regular-grade gasoline. If you purchase regular-grade gasoline from a reliable dealer, you are almost certain to have the grade and quality of fuel needed for your machine. But it is important that you understand the principle qualities that make the fuel satisfactory as compared to low-grade (fleet) gasoline or even as compared to higher grades of gasoline. The important qualities are:

1. **Proper octane rating.**
2. **Easy starting.**
3. **High oxidation stability and freedom from gum.**
4. **Freedom from foreign matter, including water and dirt.**
5. **Use of fuel additives.**

PROPER OCTANE RATING

Your assurance of getting a fuel with adequate antiknock is shown by its octane number rating. Your operator's manual tells you what the minimum octant rating should be for your machine. Compare it with the octane rating of the fuel supplied by your dealer. He should know its octane number, but if he doesn't, he can easily find out.

If you don't understand the meaning of "octane number rating," the following discussion will help.

The **octane rating** is a method of comparing the antiknock qualities of fuels used in spark-ignition engines with standard test fuels. It has been established by the ASTM (American Society for Testing Materials). The lowest number on the octane scale is 0.

Fuels near that end of the scale have a bad tendency to knock; kerosene is one of them. Fuels with the least tendency to knock have higher octane numbers, some even higher than 100. LP-Gas and super-premium gasoline are examples of these.

You may see *two octane ratings* mentioned in your operator's manual. For example, one manual states: "The gasoline should have a minimum octane number rating of 85 (Motor Method) or 93 (Research Method)." This is confusing unless you understand that, while both methods use much the same test procedures and equipment, there are certain differences such as: engine speeds, spark advance and intake air temperatures. (For example: With the Research Method the test engine runs 600 rpm (revolutions per minute); with the Motor Method the test engine runs 900 rpm. This results in a difference in the octane number ratings between the two test methods.

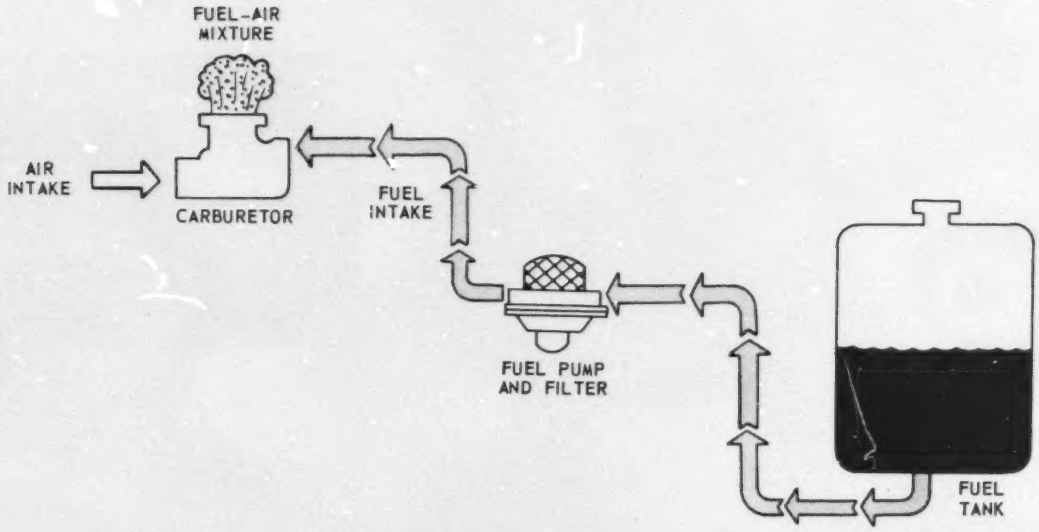

Fig. 6 — Gasoline Fuel System

For the same fuel, the Research octane number is always higher than the Motor octane number, but not by any fixed amount. The spread may vary from narrow to wide, depending on the makeup of the fuel.

If you are given the octane rating of gasoline and only one number is given with no mention of the Method, you can assume it is the *Research* octane number. This is the number most commonly used at the present time.

The names "premium," "regular" and "low-grade" are rough comparative measures of octane ratings. Most farm and industrial machines use regular grade. In fact, most manufacturers design their engines to use *regular-grade* gasoline. But over the years regular-grade fuel has gradually increased in octant rating. This has enabled manufacturers to gradually increase compression ratios in their machines to get the higher efficiencies which are made possible by higher octane fuels.

You can use premium-grade gasoline, but there is usually no advantage since most machine engines are not designed (haven't high enough compression ratio) to secure the benefits of the higher octane rating, and premium grade costs more per gallon.

If you use low-grade (fleet) gasoline, your machine will not be delivering as much power as it would with higher-octane regular-grade gasoline and you may expect your engine to knock on hard pulls. This will eventually lead to an expensive repair job. In studies of gasoline engines, it has been found that a very light knock, one you would normally not consider harmful, increases the wear on the top piston ring about 4 times more than normal.

There are several ways of improving the octane rating of gasoline. One of the most common is by adding a chemical called "tetraethyl lead" from which came the term "ethyl" gasoline. (Newer non-leaded gasolines use hydrocarbon fractions of high octane number to get the same result.)

EASY STARTING

Provision for easy starting is "built in" by both the gasoline and engine manufacturers.

The gasoline property which is most important in engine starting and performance is **volatility**. The volatility of a gasoline affects engine operation in a number of ways. If it is *too low*, insufficient vapor may be drawn into the cylinder to allow easy starting from cold, and warm-up will also be slow. On the other hand, a gasoline with *too high* a volatility is apt to cause carburetor icing and also vapor lock under adverse atmospheric conditions. A balance must be struck between these extremes. The volatility is controlled and measured by a laboratory distillation test and by a Reid vapor pressure test.

In *summer*, oil companies blend their gasolines so "volatility" — its tendency to evaporate — is low. With the higher summer temperatures, your engine will start without the gasoline having high volatility.

In *winter*, your engine will be slow to start unless the gasoline vaporizes readily; so oil companies blend gasolines for higher volatility.

If you have held over a supply of gasoline from summer to winter, you may experience hard starting. The only controls you have over volatility is to buy small quantities of gasoline and store them properly so as to keep down evaporation. This is discussed further under "Storing Gasoline Fuels," page 16.

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STORAGE STABILITY

The tendency of motor gasoline to form gum in storage is an indication of its oxidation stability.

Oxidation stability is tested by an ASTM method which measures the stability of gasoline under accelerated oxidation conditions.

In this test, a special container equipped with a pressure gauge is partially filled with gasoline; the remaining volume of the bomb is filled with oxygen at 100 pounds per square inch (689 kilopascals) pressure. The bomb is placed in a water bath at 212 F (100 C), and the time in minutes from the start of the test until the pressure drops 2 pounds in 15 minutes is reported as the induction period. The length of the induction period is an indication of the oxidation resistance of the sample since the pressure drop is indicative of the start of the oxidation of the unstable components in the sample. Most modern gasolines have induction periods which exceed 240 minutes.

This method was developed when unstable thermally cracked gasoline stocks were widely used. Its usefulness has decreased with the trend to gasoline stocks of greater inherent stability .

Most of today's gasolines are also adequately stabilized by antioxidant additives that minimize gum formation and lead antiknock decomposition.

FREEDOM FROM FOREIGN MATTER

Freedom from dirt and moisture is mostly a matter of how gasoline is handled and stored. Most distributors of petroleum products are well equipped and careful in handling fuels to avoid dirt. The dirt and moisture problem usually develops during handling and storage on the farm or jobsite. This too is discussed further on page 18.

GASOLINE ADDITIVES AND THEIR FUNCTIONS

Additives have played an important role in gasoline since fuel containing tetraethyl lead was first marketed in 1923.

Additives have become essential ingredients of modern gasolines. Except for TEL, which was introduced 38 years ago, widespread use of most additives has occurred during the past decade.

Additives are used to raise octane number and to combat surface ignition, spark plug fouling, gum formation, rust, carburetor icing, deposits in the intake system, and intake valve sticking.

In most cases, a chemical compound satisfies one of these functions. In some cases, however, an additive may perform more than one job. For example, a carburetor detergent may also serve as an anti-icing agent and a corrosion inhibitor.

Let's look at some of the major gasoline additives.

1. Antiknocks

Antiknock compounds are used to combat the tendency of a gasoline to knock in a spark-ignition engine. Ideally, gasoline should burn smoothly and evenly in the combustion chambers of an engine.

However, gasoline is composed of hundreds of different hydrocarbons, many of which may react rapidly and very violently when compressed and heated in the presence of air. After ignition, the spreading flame front in an engine's combustion chamber further compresses and heats the fuel-air mixture ahead of it. Under these conditions, some hydrocarbons in the unburned end gas may undergo chemical reactions prior to normal combustion. The products of these reactions may then self-ignite. When this happens, the end gas burns very rapidly — at a rate 5 to 25 times that of normal combustion — causing high-frequency shock waves that produce the sharp metallic noise called knock.

Besides producing an objectionable sound, a "knocking" engine may give less power and poorer fuel economy. Severe knock also tends to increase piston-ring wear and to cause overheating of valves, spark plugs, and pistons, shortening their service life and promoting destructive preignition.

FACTORS AFFECTING KNOCK

The presence or absence of knock in an engine is determined by two factors — antiknock quality (octane number) of the gasoline and the octane-number requirement of the engine.

Higher gasoline octane numbers (more resistance to knock) can be achieved in two ways:

a) By refining processes, such as catalytic reforming, which convert low-octane hydrocarbons to high-octane hydrocarbons.

b) By using antiknock additives.

Selection of the route to be used is dictated by cost and usually involves a combination of processing and antiknocks.

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The octane number requirement of an engine depends on how its design and operating conditions affect the temperature and pressure of the end gas in the engine.

An engine's tendency to knock varies with the compression ratio, spark advance, manifold vacuum, engine speed, combustion chamber design, air-fuel ratio, altitude, and atmospheric conditions.

TETRAETHYL LEAD

TEL is a highly effective antiknock that is the best choice for the majority of gasoline blends. The addition of 3 ml. TEL per gallon provides an average gain of about 10 octane numbers in modern gasolines.

The precise mechanism by which TEL controls knock is not known, despite extensive research in engines and laboratory devices of many kinds. However, it is generally believed that TEL must decompose before exerting its antiknock action. Evidence indicates that a fine dispersion of solid lead oxide or lead material is the active agent in combating knock. The small particles of the dispersion are believed to interrupt the preflame chain-branching reactions leading to autoignition of the fuel-air charge. This interruption slows the reaction rate, thereby preventing knock.

NOTE: Newer non-leaded gasolines use hydrocarbon fractions of high octane to replace the lead additives and so reduce air pollution.

SCAVENGERS

When a gasoline containing a lead antiknock alone is burned in a spark-ignition engine, it produces nonvolatile combustion products. Therefore, commercial antiknock fluids contain scavenging agents — ethylene dibromide and/or ethylene dichloride — which transform the combustion products of the antiknock into forms which are vaporized readily from hot engine surfaces. These scavengers are included as a part of any antiknock compound containing lead.

2. Deposit Modifier Additives

Deposit modifiers combat surface ignition and spark plug fouling by altering the chemical character of combustion-chamber deposits.

SURFACE IGNITION

Surface ignition occurs when the fuel-air charge is ignited by hot spots within the combustion chamber, including glowing deposits.

To the operator, surface ignition usually reveals itself either as sporadic high-frequency knocking called "wild ping" or as low-frequency noises, similar to those produced by bad main bearings, called "rumble."

Wild ping results when the surface-ignited flame front causes the pressure and temperature in the unburned portion of the fuel-air charge to rise much faster than in normal combustion. Consequently, the unburned fuel-air mixture is stressed far beyond its antiknock quality and knock results.

Rumble, on the other hand, is a form of non-knocking combustion. It occurs when ignition from a number of sources produces a very rapid pressure rise and high peak pressures during the compression stroke of the engine cycle.

In extreme cases, surface ignition can heat deposits and engine parts to the point where ignition occurs progressively earlier in the cycle. Such runaway pre-ignition can quickly burn holes in pistons or exhaust valve faces.

Phosphorus compounds are widely used as deposit modifiers. These additives suppress surface ignition by raising the temperature required to initiate glowing of deposits and by reducing the rate of heat release from oxidation of the deposits.

Some refiners use a boron compound to combat surface ignition. In addition, boron promotes the antiknock action of TEL in certain types of gasolines. This results from the ability of the boron to prevent normal sulfur concentrations in gasoline from reducing the antiknock effectiveness of TEL.

SPARK PLUG FOULING

Fig. 7 — Deposit Fouling Of Spark Plug

Combustion products tend to deposit on spark plug insulators (Fig. 7) when an engine is operated under light-duty low-temperature service, such as in stop-and-go driving. Subsequent acceleration raises the temperature of these deposits. Since the electrical resistance of the deposits decreases with rising temperature, the deposits may become suf-

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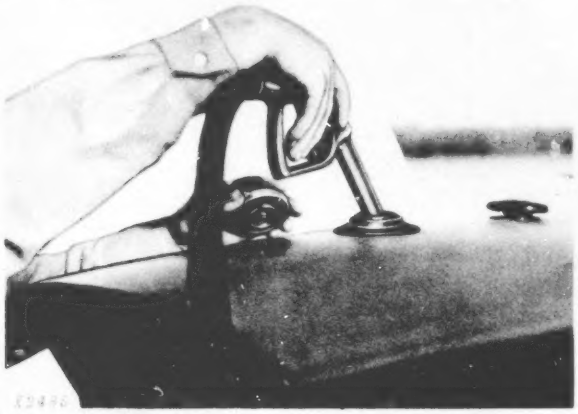

Fig. 8 — Use Only A Good Grade Of Gasoline

ficiently conductive to prevent the plugs from firing. Such misfiring usually occurs at high engine speeds or during acceleration in the middle-speed range.

To alleviate spark-plug fouling, phosphorus compounds in gasoline fuel change the deposits to forms having much higher electrical resistance over a wider temperature range.

3. Antioxidants

Antioxidants are added to gasoline to prevent gum formation during the normal life of the finished fuel.

Gum forms in gasoline when the unstable hydrocarbons combine with oxygen (oxidize) or with each other (polymerize). Gum formation is influenced by the type of crude oil from which the gasoline is produced, the refining processes used, storage temperature, extent to which air is present, and the length of storage.

When gum is formed, it produces a varnish-like deposit that tends to coat and clog the fuel lines, carburetor jets, and intake manifold, and may also cause intake valves to stick.

The oxidation stability of gasoline can be improved by various refining treatments, such as caustic washing, acid washing, partial hydrogenation, and contacting with activated clays. However, such processing is usually quite expensive and tends to rob the gasoline of the unsaturated, high-octane, olefinic hydrocarbons. Therefore, refiners frequently find it more economical to use small quantities of an antioxidant to supplement or replace processing.

Antioxidants retard the oxidation and polymerization of the unstable hydrocarbons. Although the mechanism of this action is not well defined, antioxidants are believed to act as "chain-breakers" in the various oxidation and polymerization reactions.

4. Antirust Agents

Rusting and corrosion can lead to severe problems in storage tanks, lines, and the fuel systems of engines.

For example, leaks may develop in corrosion-weakened tanks or lines. Or particles of rust may impede engine operation by clogging filters and carburetor jets. In addition, a rust particle lodged on the seat of a carburetor's needle valve may cause the float bowl to overflow, followed by engine stalling due to "flooding."

Rusting and corrosion of iron and bimetallic parts are promoted by small amounts of water and air dissolved in gasoline. Water can enter the fuel system of an engine by condensation in the fuel tank or by being pumped in with the gasoline.

Several types of hydrocarbon-soluble compounds are used as rust inhibitors. These include various fatty acid amines, sulfonates, alkyl phosphates, and amine phosphates. Most of them act by coating metal surfaces with a very thin protective film which keeps water from contacting the surfaces.

This "surface active" property can also help to prevent carburetor icing and the build-up of carburetor deposits.

5. Anti-Icing Agents

Ice can interfere with engine operation either by plugging fuel lines or by upsetting carburetion through ice formation in the air or fuel passages.

Plugging of fuel lines stems from water present in the fuels. Carburetor icing, however, is caused by freezing of water vapor from the air the engine breathes.

When a cold engine is started under certain atmospheric conditions — the most critical being from 30 to 50°F (– 1 to 10°C) at relative humidities above 65% — the cooling effect of fuel vaporizing in the carburetor causes the moisture in the air to condense and freeze on the chilled carburetor surfaces. When the throttle is almost completely closed for idling, this ice tends to bridge the small gap between the throttle blade and the throttle body, cutting off the air supply and stalling the engine. Opening the throttle for restarting breaks the ice bridge but does not eliminate the possibility of further stalling before the engine and carburetor have fully warmed up.

Two general types of carburetor anti-icing additives — *freezing-point depressants* and *surface-active agents* — are used in many gasolines to avoid the annoyance of cold-weather stalls during engine warm-up.

The freezing-point depressants serve as antifreezes, combating carburetor icing in much the same way as antifreeze provides winter protection in an engine's cooling system. These anti-icing additives, which include alcohols, glycols, and a formamide, reduce ice formation by lowering the freezing point of the water vapor in the air.

The surface-active agents provide a different kind of protection. With these agents, ice particles are allowed to form. However, the additive provides a coating which tends to prevent these particles either from sticking to each other or from building up on the metal surfaces of the carburetor. Instead, most of the ice particles pass harmlessly through the carburetor into the intake manifold. Examples of this type of additive are amides, amines, and amine or ammonium salts of phosphates.

Some freezing-point depressants and, to a lesser extent, some surface-active agents are also effective in preventing ice plugging of fuel lines.

6. Carburetor Detergents

When an engine is idling, nonvolatile fuel components, together with contaminants from exhaust and crankcase fumes drawn in through the air cleaner, tend to accumulate on the inside walls of the carburetor just below the throttle blade. By interfering with air flow and upsetting the air-fuel ratio, these deposits can lead to rough idling with frequent stalls and reduced performance and fuel economy of the engine.

Detergent additives are used to prevent deposit buildup in carburetors and to remove deposits already formed. The effectiveness of these detergents, which include amides and alkyl amine phosphates, stems from their surface-active properties.

7. Dyes

Dyes are added to gasolines to indicate the presence of antiknocks, promote sales appeal, and identify various makes or grades of gasoline. Dye is included in leaded fuel to identify its use as a motor fuel only and to warn against its misuse for heating or cleaning purposes.

Gasoline dyes are hydrocarbon-soluble organic compounds which are selected for the color they impart to the fuel.

Dye concentration depends on the intensity of color desired by the refiner to meet a color standard.

SELECTING FUEL FOR LP-GAS ENGINES

LP-Gas is short for "liquefied-petroleum gas." It is sometimes indicated as LP-G. An LP-Gas system is shown in Fig. 9.

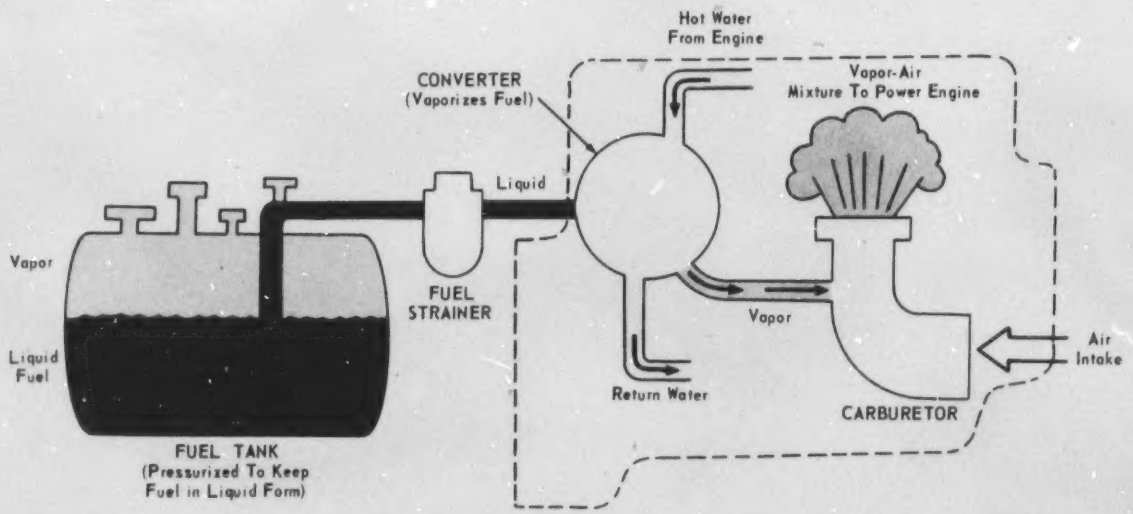

Fig. 9 — LP-Gas Fuel System

LP-Gas may be:

(a) all propane

(b) all butane

(c) a combination of the two gases

Today, LP-Gas is either all propane or mostly propane because of the high demand for butane in the chemical industry. Both products are gases and cannot be used through a regular gasoline tank and carburetor. The reason: They must be stored and handled in high-pressure containers to keep them in liquid form. Butane boils at approximately 33 F (0 C) while propane boils at −44 F (−42 C).

When confined to a closed container, the pressure varies with the outside temperature. Butane develops 37 pounds (255 kilopascals) pressure at a 100 F (38 C) while propane develops 195 pounds (1340 kilopascals) pressure at the same temperature.

An LP-Gas engine is similar to a gasoline engine, but is designed with a higher compression ratio — about 7.8 to 1 to as high as 10 to 1. Both gases have a high *octane rating* ranging from about 95 for butane to as high as 125 for propane. With such a high octane rating they are well-fitted to high-compression engines. In fact, higher compression enables these fuels to supply power economically even though they actually contain less energy per gallon than gasoline, kerosene or "tractor fuel."

Machines equipped for LP-Gas use the vapor in the top of the fuel tank (Fig. 9) for *easy starting* because it is already vaporized.

There is very little you can do about selecting LP-Gas fuel except to deal with a reliable distributor. You are entirely dependent on him to supply fuels that are relatively *free of sulfur compounds and other contaminants* which may cause difficulties such as filter plugging, valve failures, etc. However, customers seem to have had very little bad experience from impurities in LP-Gas fuel.

For cold weather operation, your dealer may have a different blend of LP-Gas than for warmer weather.

SELECTING FUEL FOR DIESEL ENGINES

There is a saying that 'Diesel engines will burn anything." It is true that they will burn a wide variety of fuels; in fact, powdered coal was the first fuel used for diesel engines.

From this you may gain the wrong impression — that selecting fuel for your diesel engine is simply supplying anything it will burn; but diesel fuel selection is far more critical than this. In fact, you need to know more about the qualities of diesel fuels than about gasoline quality for gasoline engines.

Before studying diesel fuel selection, we must first understand how a diesel engine works. Figure 2 shows the operating principles for a 4-stroke cycle engine as compared to a gasoline engine.

Note that there is no spark plug to start the fuel burning. Instead, the air is compressed until it is so hot that fuel injected into it will start burning spontaneously (Fig. 10).

The compression ratios for diesel engines are much higher than for spark-ignition engines. This extra compression of the air provides high enough temperatures (900 to 1200°F) (480 to 650°C) that the fuel is ignited by itself when sprayed into the cylinder. Note in Fig. 2 that the compression ratio is 16 to 1. This compares with the compression ratios of about 8 to 1 in gasoline engines.

The average compression ratio for diesel tractors is approximately 16.3 to 1. They vary from as low as 14 to 1 to as high as 20 to 1.

Let's look at the diesel combustion cycle a little closer.

THE DIESEL CYCLE

In the *spark-ignition* engine, the charge of fuel and air is taken into the cylinder as a mixture, compressed, and ignited by the spark plug.

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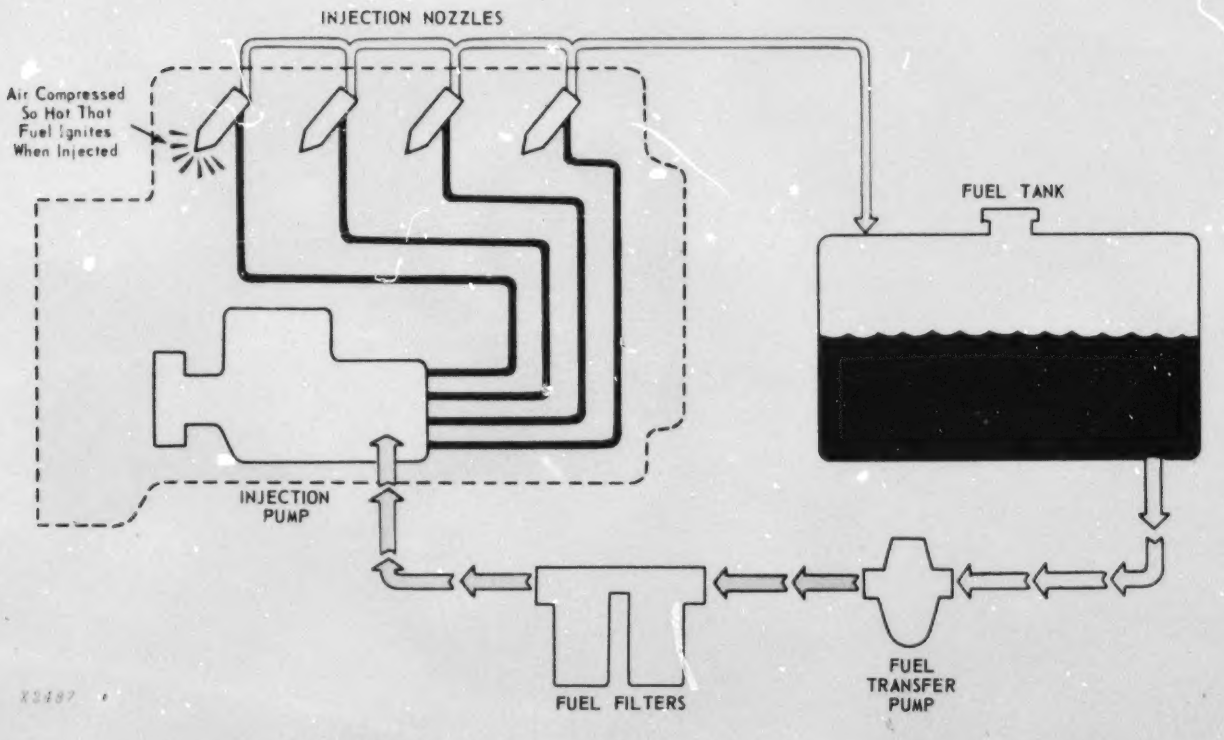

Fig. 10 — Diesel Fuel System

By comparison, in the *diesel engine*, air alone is taken into the cylinder and compressed. The fuel is injected at high pressure through a nozzle into the compressed air charge, and is ignited by the heat of this charge.

During injection, it is vital that the atomized fuel particles are fully mixed with the molecules of hot compressed air so that the maximum possible number of ignition points are created throughout the charge to provide early and uniform ignition.

Depending on the compression ratio, the temperature of the intake air, and the injection timing, the temperature and pressure of the compressed air at the time the fuel enters the cylinder may be as high as 1200°F (650°C) and 900 pounds per square inch (6200 kilopascals).

The speed and power output of the diesel engine are regulated by the amount of fuel injected per stroke. At any given engine speed, the amount of air taken into the engine usually remains constant regardless of load, and there is always an excess amount of air to burn the amount of fuel injected. This means that the overall air-fuel ratio in a cylinder must always be leaner than that required to completely burn the fuel. However, since diesel engines smoke on occasion, incomplete burning will occur under certain conditions. The two most likely causes of black smoke are faulty fuel injection or overfueling. White smoke, which may occur during idling or other cool-engine operation, is caused by unburned or partially burned fuel.

To obtain an understanding of the major requirements for a diesel fuel it is necessary to consider the diesel combustion process.

It would be reasonable to assume that ignition occurs the instant the fuel particles contact the high-temperature air within the combustion chamber. However, this does not happen. Pressure measurements made during the compression and power strokes indicate that there is a slight delay between the start of fuel injection and the time that sufficient energy is released by burning to increase the pressure above that obtained by compression of the air alone.

The ignition delay is an important factor in diesel engine combustion. Too long a delay period at high engine loads results in a too rapid increase in pressure when the fuel starts to burn. The rate of pressure rise may become so rapid at high engine loads that knock or rough engine operation will occur. For many years this sudden increase in pressure was attributed to accumulation of fuel in the combustion chamber. However, evidence is

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mounting to support the theory that a long delay period allows more time for certain chemical reactions to take place in the fuel-air mixture before ignition occurs. These reactions result in products which burn very rapidly, causing excessively rapid pressure rise. With a short delay period, ignition apparently occurs before these reactions have proceeded far enough to cause too rapid burning. Also, with a cold engine and low intake air temperatures, too long a delay period produces misfiring and uneven or incomplete combustion, with consequent smoke and loss of power.

Although the ignition delay is influenced by engine operating conditions, it depends primarily on the hydrocarbon composition of the fuel and, to a lesser extent, on its volatility.

These characteristics of diesel fuel we will cover below.

DIESEL FUEL CHARACTERISTICS

To insure the proper characteristics and maintain the uniformity of product, the refining processes used to produce diesel fuel must be closely controlled.

The American Society for Testing Materials (ASTM) has established a classification of diesel fuels in terms of their general usefulness for various types of diesel engine service.

The major grades covered in the ASTM "Tentative Classification of Diesel Fuel Oils" are:

- **No. 1-D Diesel Fuel**
- **No. 2-D Diesel Fuel**

Both are used on high-speed diesel engines on the farm and in industry.

Grade No. 1-D

Grade No. 1-D is the class of *volatile* fuel oils from kerosene to the intermediate distillates. These fuels are for use in high-speed engines in services involving frequent and relatively wide variations in loads and speeds, and also where abnormally *low fuel temperatures* are encountered.

Grade No. 2-D

Grade No. 2-D is the class of distillate gas oils of *lower volatility*. These fuels are for use in high-speed engines in services involving relatively high loads and uniform speeds, or in engines not requiring fuels having the higher volatility or other properties specified for Grade No. 1-D.

The limiting requirements by ASTM for these grades of diesel fuels are shown in the chart. Some of these fuel characteristics are discussed below. Remember that engine design and operation materially affect the type of fuel best suited for an engine.

Cetane Number

The method for determining the ignition quality of diesel fuel in terms of *cetane number* is similar to that used for determining the antiknock quality of gasoline in terms of octane number.

As in the case of the octane number scale, the scale of cetane number represents blends of two pure hydrocarbon reference fuels. Cetane is a hydrocarbon with very high ignition quality, and was chosen to represent the top of the scale with a cetane number of 100. The hydrocarbon called alpha-methylnaphthalene has very low ignition quality, and was chosen to represent the bottom of the scale with a cetane number of zero. Blends of these

ASTM LIMITING REQUIREMENTS FOR DIESEL FUELS

Diesel Fuel ***	Flash Point, Temp.	Pour Point, Temp.	Water and Sediment, % vol.	Carbon Residue on 10% Residuum. %	Ash, % wt.	90% Distillation Temperature,		Kinematic Viscosity at 100°F, Centistokes		Sulfur % wt.	Copper Strip Corrosion	Cetane Number
	Min.	Max.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Max.	Max.	Min.
No. 1-D	100°F (38°C)	*	Trace	0.15	0.01	–	550°F (290°C)	1.4	2.5	0.50	No. 3	40
No. 2-D	125°F (52°C)	*	0.05	0.35	0.01	540°F** (280°C)	640°F (340°C)	2.0**	4.3	0.50	No. 3	40

** For cold weather operation, the pour point should be specified 10°F (−12°C) below the ambient temperature at which the engine is to be operated except where fuel oil heating facilities are provided.*

*** When pour point less than 0°F (−17°C) is specified, the minimum viscosity shall be 1.8 cs and the minimum 90% point shall be waived.*

**** A diesel fuel of low volatility, No. 4-D, is recommended only for low- and medium-speed engines.*

two hydrocarbons represent intermediate ignition qualities, and their cetane number is the percentage of cetane in the blend. For example, a reference fuel blend containing 30 percent cetane and 70 percent alphamethylnaphthalene is assigned a cetane number of 30.

The engine used in cetane number determinations is a standardized (ASTM) single-cylinder, variable-compression-ratio engine with special loading and accessory equipment.

Under test, the compression ratio of the test engine is varied until combustion starts at top dead center. With the start of fuel injection timed at 13°BTDC and with combustion timed to start at top dead center, an ignition delay period of 13° (2.4 milliseconds at 900 rpm) is produced.

This procedure is then repeated using reference fuel blends until the unknown fuel is bracketed between two reference blends differing by not more than 5 cetane numbers. Then, knowing the cetane numbers of the bracketing blends and the compression ratios required by the fixed delay period for both the reference blends and the sample fuel, the cetane number of the sample can be obtained by calculation.

The cetane number of a diesel fuel depends primarily on its hydrocarbon composition. In general, the aromatic hydrocarbons are low in cetane number, the paraffins have high cetane number, and the naphthenes fall somewhere in between. Thus, it is apparent that the base stocks and refining processes used in making diesel fuels are all-important in determining ignition quality. The refiner is constantly faced with the problem of blending stocks to achieve adequate ignition quality without sacrificing other necessary characteristics, such as pour point and volatility.

The ignition quality of a diesel fuel can also be improved by the use of additives, such as amyl nitrate. The relationship between the cetane number of a diesel fuel and the performance of a diesel engine should not be confused with the relationship between the octane number of gasoline and the performance of a spark-ignition engine.

In gasoline engines, raising the octane number improves potential engine performance via increased compression ratio or supercharging, and the octane number requirement is usually fixed by the full-load demand of the engine.

In diesel engines, the desirable level of cetane number is established by the requirements for good ignition quality at light loads and low temperatures.

In general, *high*-cetane fuels permit an engine to be started at lower air temperatures, provide faster engine warm-up without misfiring or white smoke, reduce the rate of formation of varnish and carbon deposits, and eliminate combustion roughness or diesel knock.

However, *too-high* cetane numbers may lead to incomplete combustion and exhaust smoke if the ignition delay period is too short to allow proper mixing of the fuel and air within the combustion space.

Diesel fuels marketed in the United States range from 33 to 64 in cetane number.

Knock In Diesel Engines

In a *spark-ignition engine*, where the fuel-air charge is mixed and then compressed before ignition takes place, *knock is caused by the fuel burning TOO RAPIDLY*. To control the rate of burning, tetraethyl lead is added.

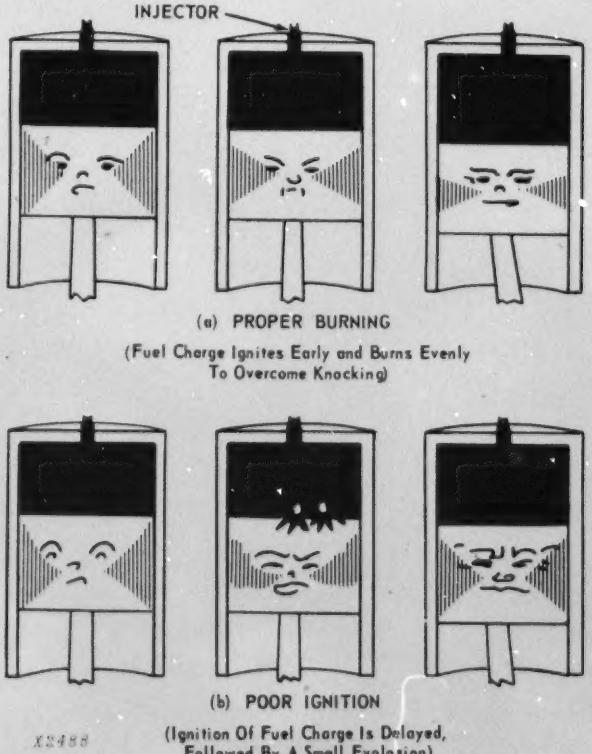
INJECTOR
(a) PROPER BURNING
(Fuel Charge Ignites Early and Burns Evenly To Overcome Knocking)
(b) POOR IGNITION
(Ignition Of Fuel Charge Is Delayed, Followed By A Small Explosion)
X2488

Fig. 11 — In Diesel Engines Knock Is Due To Fuel Igniting Too Slowly

In diesel engines, knock is due to the fuel igniting TOO SLOWLY (Fig. 11). It should start to burn almost as soon as it is injected (A). If there is much delay, a fuel build-up results which burns with explosive force (B) and causes knocking.

Good diesel fuel provides for *early* spontaneous combustion. By contrast, good gasoline fuels avoid spontaneous burning.

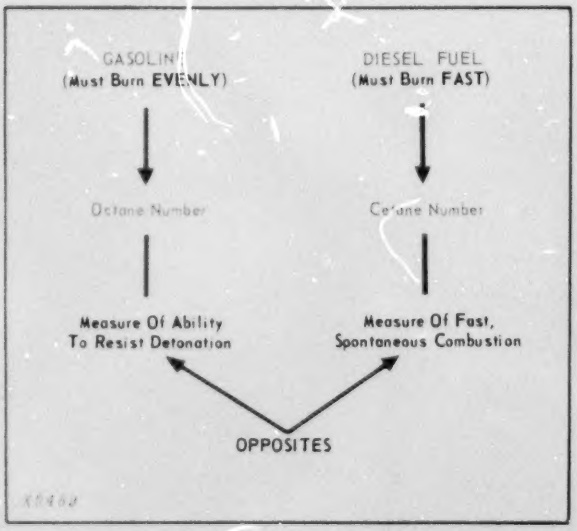

Fig. 12 — Octane And Cetane Numbers Are Opposites

The differences between octane numbers (gasoline) and cetane numbers (diesel fuel) are shown in Fig. 12.

Volatility

The distillation characteristics of a diesel fuel are essential for good combustion in the diesel engine. The characteristics are achieved by a careful balancing of the light and heavy petroleum fractions during the refining process. The components of the blend which boil at the highest temperatures have higher heating values than do the lighter fractions.

Although a lot of *heavy* fractions in the final product may improve good fuel economy, it can be harmful due to deposit formation within the engine.

Too many *light* fractions may provide easier engine starting and more complete combustion under a variety of engine conditions. However, the light ends are generally low in ignition quality. Moreover, they do not release as much energy per gallon as do the heavier fractions.

Volatility characteristics also influence the amount and kind of exhaust smoke and odor. The temperatures at which 10%, 50%, and 90% of the fuel is evaporated during a distillation test are important control points in achieving best volatility balance.

Pour Point

Diesel fuel must be able to flow at the lowest expected atmospheric temperatures. The lowest temperature at which the fuel ceases to flow is known as its *pour point*.

As fuel temperature decreases toward the pour point, the fuel becomes sluggish and harder to pump through the fuel supply lines, fuel filters, and injection system.

The pour-point temperature of a fuel is closely related to the molecular structure of its component hydrocarbons. For example, the naphthenes tend to have low pour points and relatively low cetane numbers, whereas the paraffins tend to have high pour points and relatively high cetane numbers.

Since low pour points often can be obtained only at the expense of lower cetane number or higher volatility, the pour-point specification should not be any lower than necessary.

Cloud Point

Diesel fuel becomes cloudy and forms wax crystals and other solid substances at some temperature above the pour point. The temperature at which clouding begins is called the *cloud point*.

Since the wax crystals clog fuel filters and supply lines, and since this occurs at temperatures above the pour point, the cloud point may be even more important in a fuel specification than the pour point. Like the pour point, the cloud point depends on the hydrocarbon composition of the fuel.

Although cloud points seem to occur from 8 to 10°F (−13 to −12°C) above the pour points, cloud point as high as 15 or even 20°F (−9 to −7°C) above the pour points are not uncommon.

Viscosity

Diesel engine injection pumps perform most effectively when the fuel has the proper "body" or *viscosity*. The lower viscosities may require more frequent maintenance of injection systems parts. Viscosity also has some influence on the atomization of the fuel when it is injected.

If the viscosity is too high, excessively high pressures can occur in the injection system. Therefore, the proper viscosity or resistance to flow of diesel fuel becomes a prime requirement.

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Gravity

The *gravity* of diesel fuel is an index of its density or weight per unit volume. The denser the fuel, the higher is its heat content. Since fuel is purchased on a volume basis, gravity is used in purchasing specifications and sometimes in delivery inspections. Gravity is measured in "degrees API." The higher the API gravity of a fuel, the lower is its density or specific gravity.

In general, the refiners choice of blending stocks and refining processes to achieve the desired volatility characteristics and cetane number determines what the gravity will be.

Flash Point

The *flash point* is the temperature to which the fuel must be heated to create a sufficient mixture of fuel vapor and air above the surface of the liquid so that ignition will occur when the mixture is exposed to an open flame. Various states and insurance companies have mandatory requirements for flash point based on fire hazard, which must be taken into account when writing diesel-fuel specifications.

Carbon Residue

The tendency of a diesel fuel to form carbon deposits in an engine may be roughly approximated by determining the carbon residue of the fuel. *Carbon residue* is the amount of material left after evaporation and chemical decomposition of the fuel have taken place at an elevated temperature for a specified period of time. High carbon residue values indicate the possibility of increased combustion chamber deposits and exhaust smoke.

Although carbon-residue tests are fairly effective in predicting deposit formation of base fuels, they are not good predictors when the fuels contain ignition improvers.

Any specification for carbon residue should be stated for the base fuel.

Sulfur

Diesel fuels contain varying amounts of *sulfur*, depending on the crude oil source, refining processes, and grade Sulfur tends to be more prevalent in the higher boiling range fractions.

High sulfur content can become a problem in diesel engine operation at low temperatures and during intermittent engine operation. Under these conditions, where more moisture condensation can take place, cold corrosion and increased engine wear may be caused by using fuels containing excessive amount of sulfur.

Ash

Small amounts of non-burnable material are found in diesel fuel in the form of soluble metallic soaps and abrasive solids. Since diesel engine injectors are precision-made units of extremely close fits and tolerances, they are sensitive to any abrasive material in the fuel.

The ASTM method used to determine the amount of these materials in a diesel fuel measures the *ash* content of the fuel. This is done by burning a small sample of the fuel in a weighed container until all of the carbon matter has disappeared, as shown by the container and residue reaching a constant weight. The weight of the unburnable residue divided by the weight of the original fuel sample and multiplied by 100 is reported as the ash content of fuel (percent by weight).

Recommended Diesel Fuels For Farm And Industrial Machines

Below is a typical recommendation from a tractor operator's manual.

Type of Engine Service	*Ambient Air Temperature*	*Diesel Fuel Grade No.*
Light load, low speed, considerable idling.	Above 80°F (27°C) Below 80°F (27°C)	2-D 1-D
Intermediate and heavy load, high speed, minimum of idling.	Above 40°F (4°C) Below 40°F (4°C)	2-D 1-D
At altitudes above 5,000 feet.	All	1-D

Diesel Fuel Vs. Furnace Fuel

The question is often asked *if diesel fuel and furnace fuel are the same.* It is possible for your fuel supplier to have one fuel that he supplies for both diesel-engine use and heating purposes. Where there is one dominant use, such as home heating compared to limited diesel-fuel use, the dealer may not be justified in stocking a separate diesel fuel. So he purchases fuel from his supplier to meet the specifications for both fuels. The refiner can meet this demand because the specifications for both fuels are broad enough that they overlap.

If a dealer is supplying big quantities of fuel for both heating and diesel engines, he will normally

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stock two fuels. In this case the furnace oils usually contain more of the heavy cracked distillates which are quite satisfactory for furnaces but are *not* suitable for diesel engines (especially with light intermittent loads) and they do not generally meet ASTM standards for diesel engines.

Cold Weather Starting

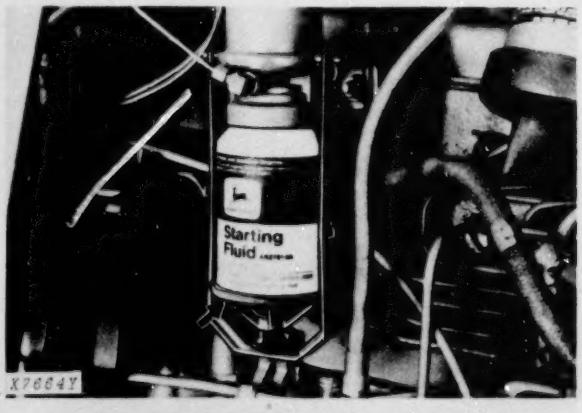


Fig. 13 — Starting A Diesel Engine In Cold Weather Using Ether Starting Fluid

The higher the cetane number, the easier your machine will start on diesel fuel. Ether has a cetane rating of 85 to 96 and is highly volatile. For those reasons, ether fluid is used for starting some diesel engines in cold weather (Fig. 13).

IMPORTANT: Spray ether into the engine ONLY while cranking it. Ether is highly volatile and build-up could damage the engine.

STORING FUELS

Your problem of storing fuels will depend on the type of fuel you are using. We have divided this discussion into three parts:

1. **Storing gasoline fuels**
2. **Storing diesel fuels**
3. **Storing LP-Gas fuels**

Each state has its own laws regarding the handling, storage and use of fuels. It is important that you become acquainted with them for your own safety and for insurance purposes.

In general, state laws are based on the standards and codes established by the National Fire Protection Association. It is their recommendations that are followed in this discussion.

Proper storing and handling of fuels can affect your safety, how easily your machine starts, and how much maintenance your fuel system requires.

A dependable fuel supplier knows the importance of delivering fuel to your farm or jobsite in top-quality condition. He is usually well-trained and equipped to do the job. But, regardless of the care he uses, improper storage and negligence on your part can offset it.

Consider these four factors in the storage of fuels:

1. **Protection of fuel quality.**
2. **Safety.**
3. **Convenience.**
4. **Cost.**

The importance of these factors varies with the type of fuel you wish to store. For example: Maintaining fuel quality is a serious problem with gasoline and diesel fuel, but it is not a problem with LP-Gas. However, with LP-Gas, safety is a bigger factor.

STORING GASOLINE FUELS

PROTECTION OF FUEL QUALITY

You must control three conditions if you are to maintain satisfactory quality in your gasoline:

(a) Control loss through evaporation.

(b) Avoid gum deposits.

(c) Protect from water and dirt.

Controlling Evaporation Losses

Evaporation losses are important both because of fuel loss and because of increased difficulties in starting your engine.

As mentioned earlier, *your fuel supplier provides different gasoline blends depending on the season of the year.*

In *winter*, the blend consists of more volatile fuels which provide for easier starting of your engine. In *summer*, when starting an engine is no problem, gasoline contains less of the lighter fuels; this keeps down evaporation losses.

But, if you hold your summer-blend fuel into the winter months, your machine will be hard to start. If you hold your winter-blend fuel for several months, the lighter-weight portions evaporate and

it will become unsatisfactory for cold-weather starting. A Purdue University report states that "A sample of gasoline in storage six months in an above-ground vented tank . . . would not be considered serviceable."

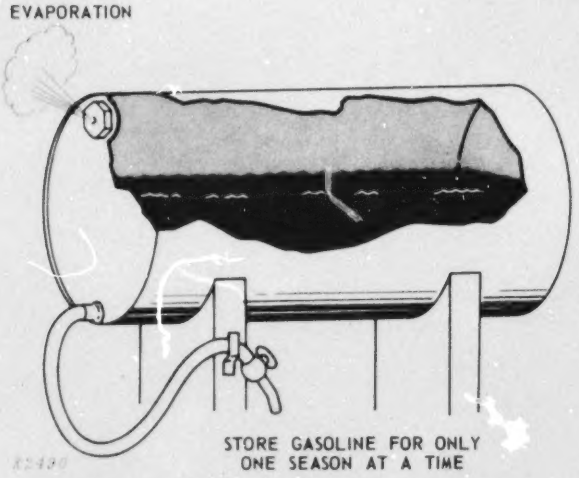


Fig. 14 — Lighter Fuels in Gasoline Blend for Easy Starting are First to Evaporate During Storage

Evaporation losses are sizeable from an *above-ground tank* unless you make some provision for shading it. Note in Fig. 15 that there are substantial losses of fuel from evaporation if the storage tank is exposed to direct sunlight and if the vapors are free to pass through an open vent.

These illustrations are based on studies conducted in Missouri where it was found that evaporation is especially rapid between the temperatures of 90 and 100 F (32 and 38 C). This accounts for the fact that a tank painted red (A, Fig. 15), which heats rapidly when exposed to sunlight, has a greater loss of fuel than a tank painted a reflective color such as white or aluminum (B). However, a tank may be almost any color if it is shaded from direct sunshine as in (C).

In the Missouri test it was also shown that winter evaporation losses are about the same as those in summer. The reason: Winter-blend fuel, with its larger amount of lighter-weight gasoline, evaporates faster (Fig. 14). This makes your machine start more easily on cold days. But when the sun shines and the tank warms, your fuel losses are about equal to those in summer.

A good shade tree might provide enough protection for a fuel tank in summer but according to the Missouri report ". . . it is possible that some of the loss due to evaporation is the result of wind motion around open vents. This may siphon gasoline vapors from the tank. Sheet metal shades may serve to block off the wind and reduce gasoline losses in this manner."

Evaporation losses can be still further reduced by use of a *pressure-vacuum release vent* shown in (D) in Fig. 15.

If you are not familiar with the operation of a pressure-vacuum valve, note Fig. 16. It can be used in place of the standard vented cap — the type in use on most tanks. Or if your tank has a separate vent (Fig. 15, D), it can be used in place of the vent.

If you should use the pressure-vacuum valve as a cap replacement and your tank has a separate vent, plug the vent. The tank must be airtight for the valve to work.

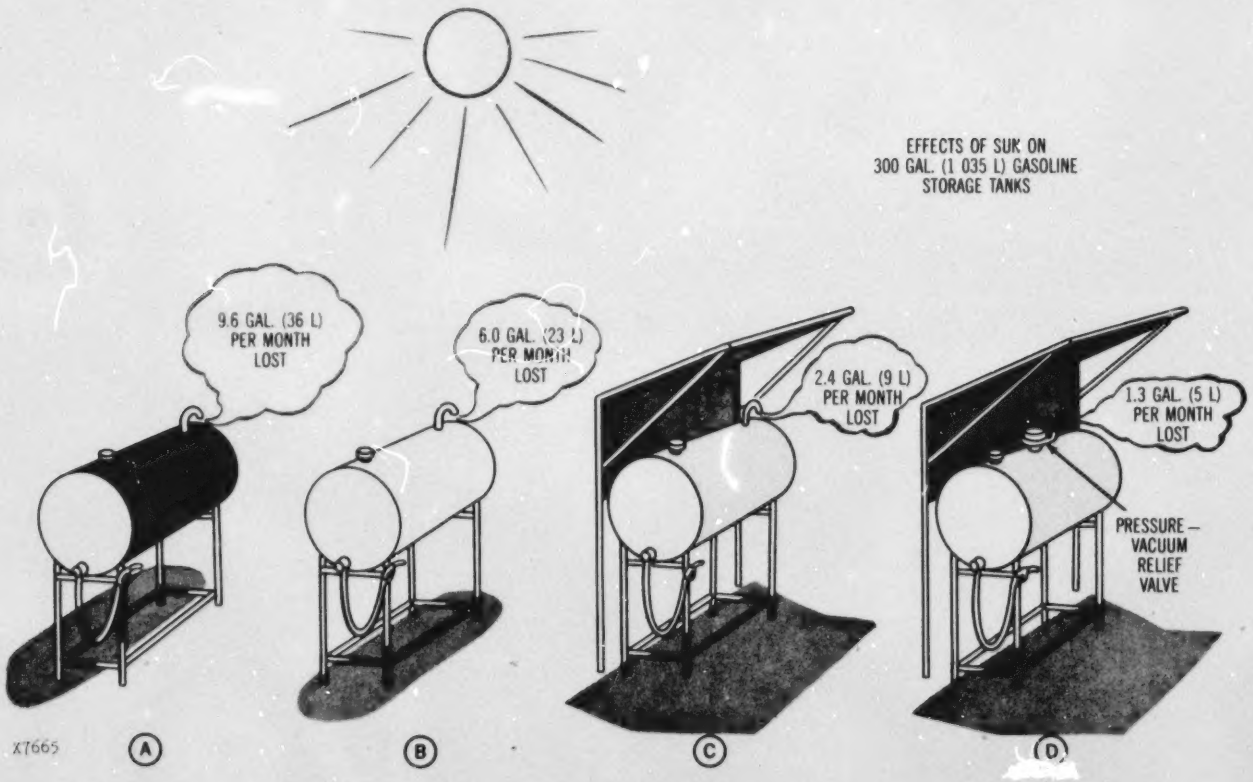
There are thousands of pressure-vacuum relief valves in use, but before installing one, check with your state fire marshal. In some states it is against the law to use them. The reason: The pressure-vacuum valve is considered as being a type of obstruction and the National Fire Protection Code states: "Vent pipes two inches or less in nominal inside diameter shall not be obstructed by devices that will reduce their capacity and thus cause excessive back pressure." Some claim the valves require occasional cleaning which most customers tend to overlook.

Some manufacturers, in an effort to meet these objections, have increased the size of the vent area and decreased the pressure required to operate the vacuum valve to as low as one ounce to provide a minimum of obstruction. This may help the situation, but it will probably take a few more years of experience with field installations before there is general agreement regarding its use.

CAUTION: Don't try sealing the vent opening in your present tank to save the cost of a pressure-vacuum valve. Under hot conditions the tank pressure can increase to a point where it might burst your tank, or if the tank is hot when sealed and then cools, a vacuum tends to develop which may cause it to collapse.

The *pressure portion of the valve* allows only 3 pounds per square inch (21 kilopascals) of pressure to develop in the tank. Above that, the pressure valve opens and allows enough vapor to escape to maintain the pressure at 3 pounds (A, Fig. 16). When the tank cools, the *vacuum valve* is forced open by atmospheric pressure so that air may enter as shown in (B). From one ounce to 3 pounds (0.4 to 21 kilopascals) of pressure may be required to open it, depending on the vacuum-valve setting.

If you use an *underground tank* (Fig. 17), the temperature of the stored fuel remains low enough all through the year so that the evaporation losses are small. Further provision for reducing evaporation losses is not necessary.



A — Red Tank Exposed To Sun's Heat
B — White Or Aluminum Tank Exposed To Sun's Heat
C — White Tank Protected By A Shade
D — White Shaded Tank Equipped With A Pressure-Vacuum Relief Valve

Fig. 15 — Summer Evaporation Losses From 300-Gallon (1035 L) Gasoline Storage Tanks

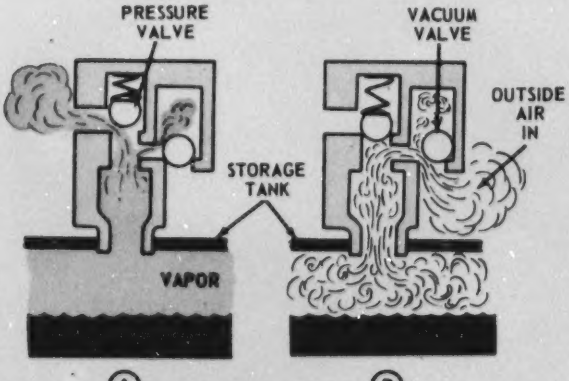

PRESSURE
VALVE
VACUUM
VALVE
OUTSIDE
AIR
IN
STORAGE
TANK
VAPOR
A
B
When Tank Pressure Rises Above 3 Psi (21 kPa), Ball On Pressure Valve Rises And Allows Enough Gasoline Vapor To Escape To Keep Pressure At 3 Psi.
When Storage Tank Cools Or Fuel Is Withdrawn, Vacuum May Develop, Causing Outside Air To Force Past Vacuum Valve and Enter Tank. This Keeps Pressure Inside Tank Near That On Outside.
X7666

Fig. 16 — Pressure-Vacuum Relief Valve To Vent Gasoline Storage Tank

Avoiding Gum Deposits

The second point to consider is that gasoline will oxidize and form *gum deposits* if kept for long periods.

Refiners of gasoline add an inhibitor that will protect the fuel for six months to a year under normal storage conditions, but the time is greatly reduced if the gasoline is exposed to sunlight and to high storage temperatures. There are also certain metals, like copper, that cause gum to form faster.

Potential gum deposits can be reduced: Avoid storing more gasoline than you can use conveniently in a period of about 30 days. This too is less of a problem with underground tanks since the fuel remains cooler.

Protecting Against Water and Dirt

The same precautions you take in keeping down evaporation losses also help reduce *moisture con-*

densation in the tank. This problem occurs more with aboveground tanks. The more the temperature of a storage tank varies the more air it "breathes in and out."The fresh warm air that is "breathed in" may contain more moisture than it can hold when the temperature drops. This causes moisture to condense on the inside of the tank and collect at the bottom under the fuel. The water must be drained or pumped out occasionally to avoid freezing, rusting and carburetor clogging.

A hand pump is used to remove water from an underground tank (Fig. 20).

There is some evidence that long storage reduces the octane number of gasoline but the reduction is not enough to concern a user.

SAFETY

If you are using an **aboveground tank** (Fig. 17), it should be located 40 feet (12 m) or further from the closest building as a fire safety precaution. This is the recommendation of the National Fire Protection Association.

However, you may locate an **underground tank** so the nearest point of the shell is as close as one foot from the wall (Fig. 17).

The NFPA standard for machine fuel storage requires that aboveground tanks which feed by gravity be equipped with valves that close automatically in case of fire. In some states the valves are required by law. If your tractor catches fire, or spilled fuel ignites while you are filling the fuel tank, the fuse link melts and a spring automatically closes the valve.

Aboveground tanks should be supported on well-built racks or on timbers or blocks, to keep them off the ground at least 6 inches (152 mm) so as to prevent corrosion of the tank.

If you install an underground storage tank, it is best to place it in a well-drained area. If it must be located where there may be high ground-water levels or flooding, provide an anchor or weight it with concrete. This will keep a partially or completely empty tank from floating out of the ground.

To protect an underground tank from outer corrosion, coat it with an asphalt tar coating or some type of mastic coating recommended for that purpose. Avoid backfilling with cinders or ashes. They corrode metal that isn't well protected.

The ground should slope away from a tank or pump so vapors can drain away. Gasoline vaporizes readily. Since the vapor is 2 to 4 times heavier than air, it will collect in low places. A spark or match will easily set it afire since air-gasoline mixtures of about 1.5 to 7 per cent gasoline vapor will burn readily.

Gasoline-air mixtures richer than about 7 per cent are too rich to burn. This is the situation with a vented gasoline tank and explains why flames burn freely at the vent opening but won't follow the vent pipe down into the tank and cause an explosion.

Label your gasoline tank, particularly if there are other tanks in the vicinity containing other kinds of fuel. A **red** tank indicates it contains gasoline. But if the tank is exposed to sunlight and you painted it white to keep down the temperature, label "GASOLINE" on it to make sure anyone drawing fuel knows exactly what he is getting. If you are using an underground tank, paint the pump red or label "GASOLINE" on it.

CONVENIENCE

For convenience, locate your fuel storage in the vicinity of your machinery storage building. If possible, allow about 50 feet (15 m) on one side of the storage tank or pump, for maneuvering your machines and equipment. This also allows plenty of room for the tank truck to get in and out.

Convenience may help determine whether you select an aboveground tank or the underground type since the latter can be located near the outside of the building where you store your machines.

COST

If you are selecting a storage tank on the basis of cost alone, the aboveground tank is much less expensive than an underground tank of the same capacity. In fact, in many localities the fuel supplier lends and aboveground storage tank to his customers as long as they purchase fuel from him.

However, if you have a choice of getting either type of storage tank installed by your dealer or if you must buy a storage tank, it is well to consider the following points along with tank cost.

Advantages of Underground Tank

1. *Less fuel evaporation.*
2. *Less water condenses in the tank.*
3. *Less gum deposits form in the fuel.*
4. *Fire hazards are reduced.*
5. *The tank is hidden, avoiding a clutter around your buildings.*

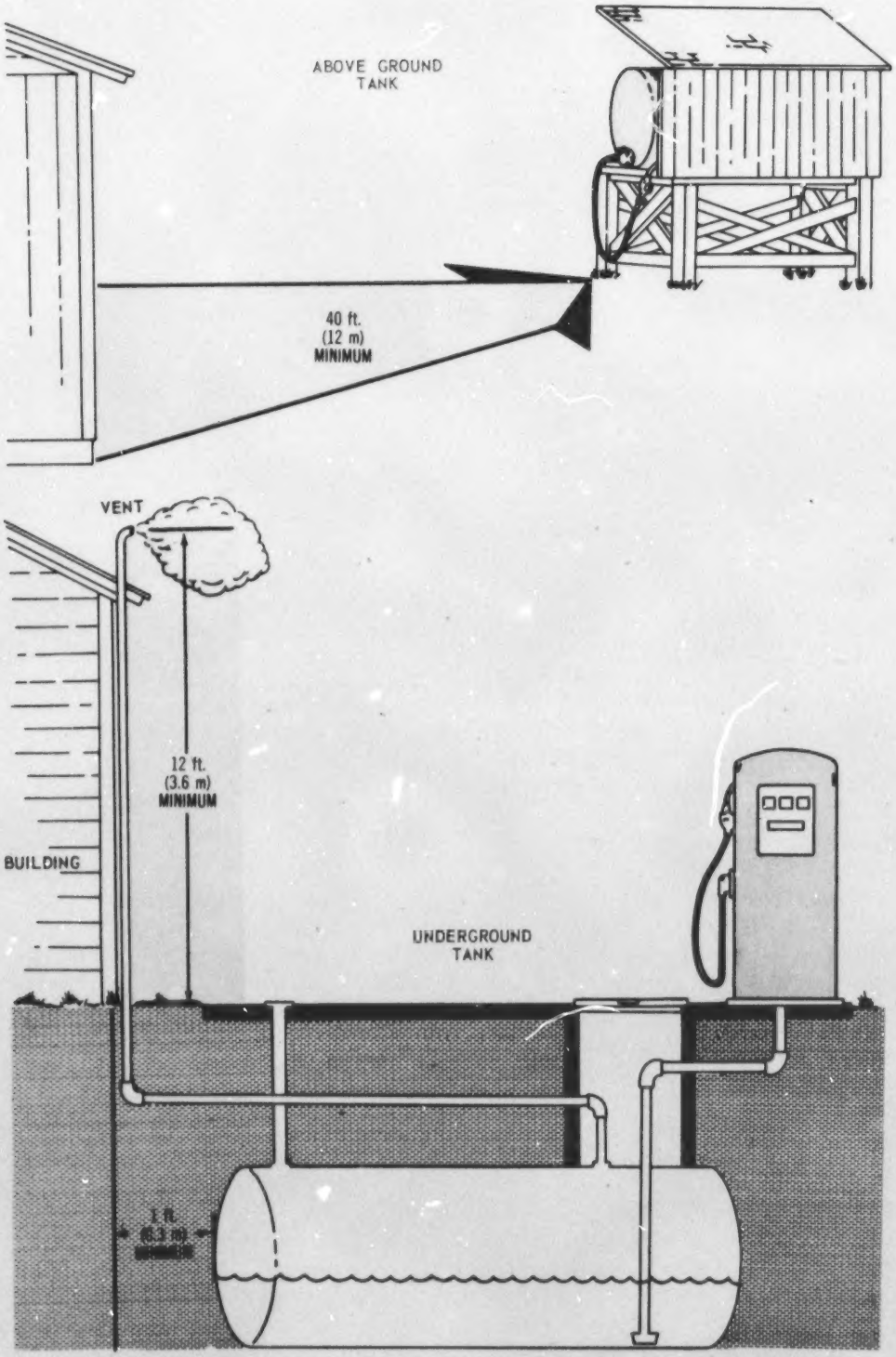


Fig. 17 — Safe Location Of Gasoline Storage Tanks In Relation To Buildings

Advantages of Aboveground Tank

1. Costs less to purchase.

2. Not affected by ground water and limited flooding.

3. Is easily moved.

The size of tank you install is the same with either type of storage since you should not install one that holds more than 30 days fuel supply.

STORING DIESEL FUELS

PROTECTION OF FUEL QUALITY

Evaporation during storage (whether above or below ground is not rapid enough with diesel fuel to be of concern. What evaporation does occur has little effect on fuel quality.
Of greatest importance in maintaining the quality of diesel fuels is that you:

(a) Keep them free of dirt and water.

(b) Avoid gum deposits.

Keeping Fuel Free of Dirt and Water

It is important that all fuels be kept *free of dirt and water*, but it is especially important with diesel fuel. The reason: The fuel injection system on a diesel engine is fitted with parts that are held within millionths of an inch clearance. Very fine dirt particles soon ruin the parts and cause an expensive repair job. Water, even extremely small amounts, causes corrosion which ruins the highly-polished surfaces of the injector nozzle. All operator's manuals for diesels emphasize the importance of clean fuel.

Water is about the same weight as diesel fuel so it settles out very slowly. For this reason, be sure to provide some arrangement that will allow 24 hours for water and dirt to settle to the bottom of the storage tank after it has been refilled by your supplier. Use of two storage tanks is best. When one is refilled you can use from the other to supply fuel for your machines.

If you have only one storage tank, be sure you fill your machine fuel tank before your supplier refills the storage tank. The filling process disturbs the water and dirt particles in the bottom of the tank and mixes them with the fuel.

If you are using *drums* for storing your fuel, be sure that they are mounted rigidly in place. Any handling will remix the dirt particles and water from the bottom of the tank with fuel.

If you are using drums as *portable tanks* for refueling in the field, be sure they are in place at least 24 hours before fuel is drawn from them.

Don't let water collect on top of your fuel storage as shown in Fig. 18 (C). There are two reasons: (a) water retained on the tank tends to rust the outside of the drum and (b) as fuel is drawn from the tank, water may be drawn through the air vent directly into your fuel supply.

Dirt particles may come from several different sources. Some may be present in the fuel when it is delivered by your supplier, but they are far more likely to come from carelessness or improper storage. Some rules for preventing dirt in the fuel supply:

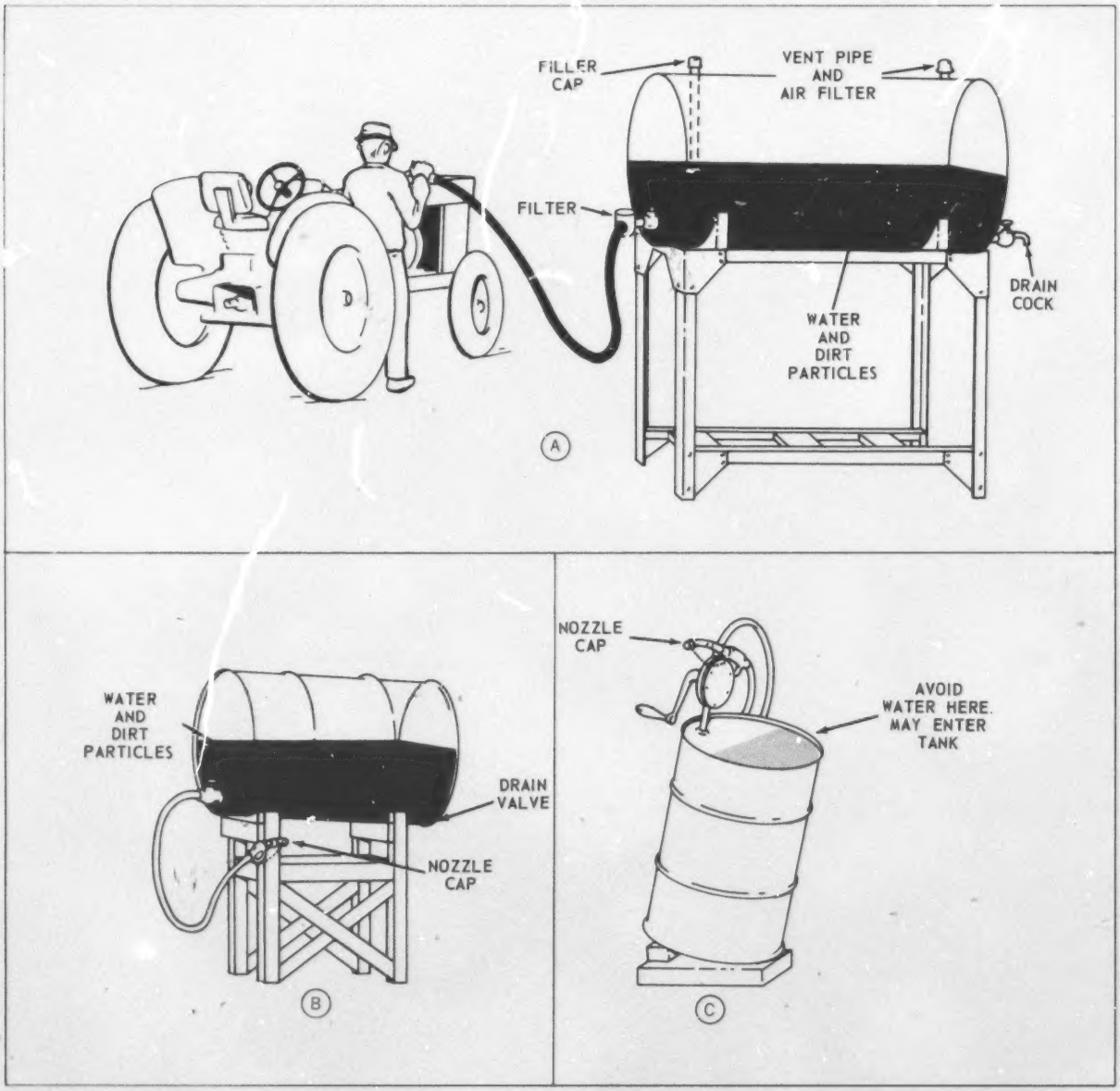
1. Don't use an open container to transfer fuel from the storage tank to the machine tank. This greatly increases the chance for dirt to enter the fuel tank. Equip your aboveground tank with a pump and hose (Fig. 18 C) or a gravity hose (Fig. 18 A and B) to transfer fuel. Then be sure to cap the end of the hose nozzle while the hose isn't in use.

2. Don't store diesel fuel in a galvanized tank. A galvanized tank is satisfactory for gasoline, but when diesel fuel is stored in it, the fuel reacts with the galvanized finish, causing powdery particles to form. They soon clog the fuel filters on a diesel engine. Use steel tanks to avoid these troubles.

3. Don't use a tank formerly used for gasoline storage. Fine rust and dirt particles that settled out of gasoline and accumulated on the bottom of the tank, mix readily with diesel fuel and may remain suspended in it until drawn from the tank.

4. Don't let the suction pipe to the fuel pump extend to the bottom of the storage tank. This permits the pump to pick up water and sediment that has settled out of the fuel. The end of the pipe should be 3 or 4 inches (76 or 101 mm) from the bottom. If possible, slope the tank away from the pipe or outlet valve (Fig. 18A).

5. Always drain the storage tank before refilling and clean the tank regularly. This may allow the dirt-and-water residue to rise high enough to be drawn out with the fuel.



A — Large Elevated Storage Tank

B — Small Drum-Type Elevated Storage Tank

C — Drum-Type Storage With Pump (Sometimes Used as Portable Fuel Supply)

Fig. 18 — Types Of Aboveground Storage Tanks For Diesel Fuel

In addition to these precautions, use a *strainer* under the filler cap or a filter at the tank outlet (Fig. 18 A). Or use both as additional precautions for removing dirt.

Draining of water and sediment from an aboveground storage tank is best accomplished by means of a valve at the bottom of the tank (Fig. 19). Don't depend on a drain plug. It is awkward to use and may result in fuel spillage and fire danger.

About twice a year (in the spring and again in the fall) *thoroughly clean the tank* as shown in Fig. 19. Rinse out loose sediment with clean diesel fuel. Contaminated fuel drained from the tank should be kept in a container for about 24 hours to allow dirt and water to settle. Then the clean portion of the fuel can be poured off and returned to the clean storage tank.

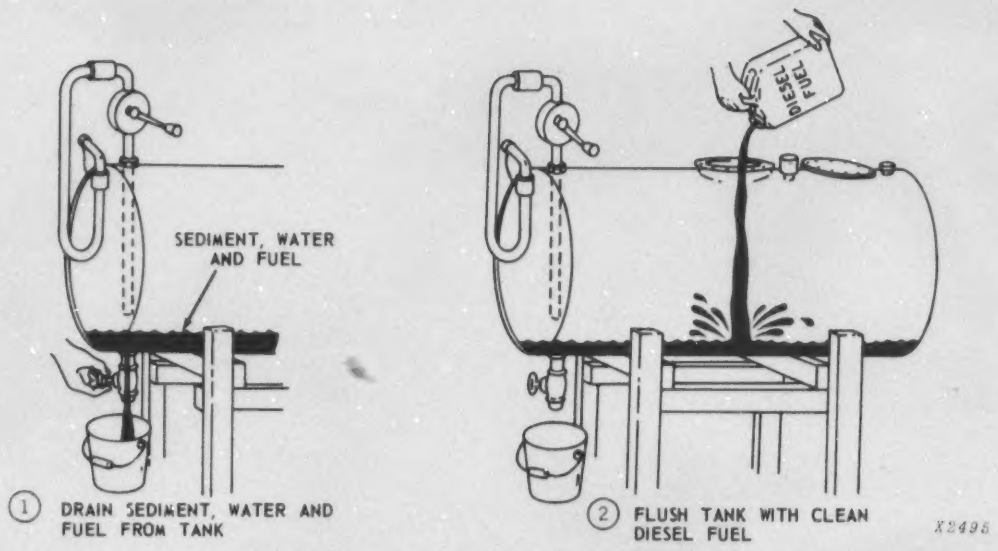


Fig. 19 — Clean Diesel Storage Tanks Twice A Year

If you are using an *underground tank*, remove the water and sediment with a hand pump (Fig. 20). Twice a year is an accepted practice.

Avoiding Gum Deposits

To keep down gum-and-varnish forming tendencies in an aboveground tank, keep it shaded from direct sunlight in the same manner as for gasoline storages (Fig. 15). This will also help to keep moisture from condensing in the tank. The fuel contains a "gum inhibitor" added by the refiners or distributor which retards the formation of gum and varnish for about three months.

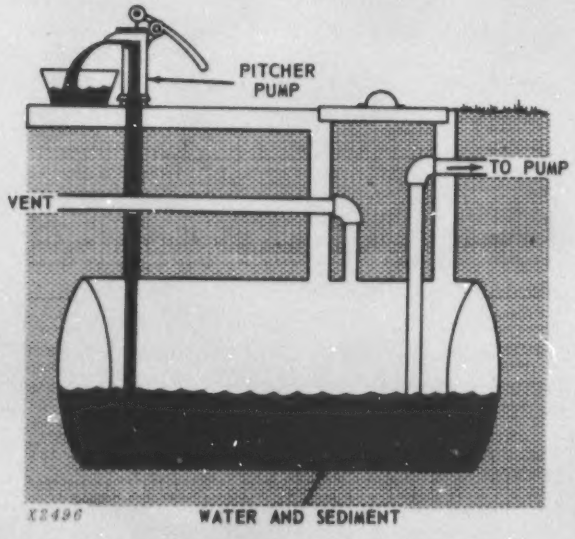


Fig. 20 — Using Hand Pump To Clean Dirt And Water From Underground Storage Tank

SAFETY

The spacing of storage for diesel fuel is the same as for gasoline storage — 40 feet (12 m) or more from the nearest building for aboveground storages and one foot or more from the foundation wall for underground storages (Fig. 17).

Many customers think that aboveground storage tanks for diesel fuel may be located next to a building. This probably comes from observing approved tank installations for oil-burning equipment installed next to a building.

But machine tanks must be filled frequently, and even though diesel fuel is much safer than gasoline, the National Fire Protection Association states that: "The occurrence of spills in handling flammable liquids is recognized as presenting the greatest potential source of the release of flammable vapors."

CONVENIENCE AND COST

When considering convenience and cost for diesel fuel storage, the same general points are involved as for gasoline storage. The exception is that evaporation is not much of a problem.

These fuels may be stored for as long as three months without seriously affecting fuel quality, while gasoline should not be stored longer than about 30 days. This may justify the use of a larger storage tank if there are times in the year when you can buy fuel at a substantial savings.

STORING LP-GAS FUELS

LP-Gas must be stored in pressure-type tanks. At ordinary temperatures it changes to gas unless kept under pressure. Consequently, storage of LP-Gas is an entirely different problem from storing gasoline and diesel fuel.

There is no problem of protecting fuel quality. And there is virtually no evaporation from the pressure tank, nor does the fuel change chemically during storage. This enables you to have as large a tank as you wish and keep the fuel for as long as you wish.

The remaining factors of *safety, convenience* and *cost* are discussed below.

SAFETY

Since LP-Gas is kept under pressure and is highly flammable, rigid standards have been established by the National Board of Fire Underwriters for construction of LP-Gas storage tanks. You can tell if your tank has met Underwriters Laboratories' standards by the label on the nameplate (Fig. 21).

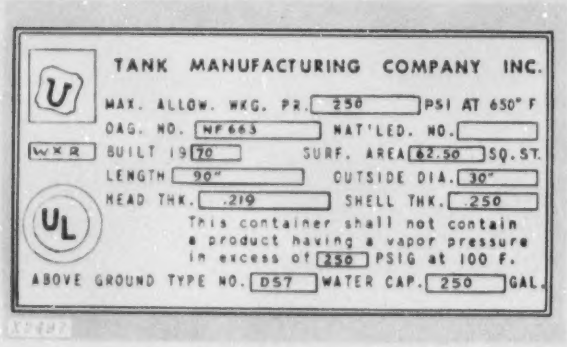

TANK MANUFACTURING COMPANY INC.
MAX. ALLOW. WKG. PR. 250 PSI AT 650° F
DWG. NO. NF663 NAT'LED. NO.
WXR BUILT 19 70 SURF. AREA 62.50 SQ. ST.
LENGTH 90" OUTSIDE DIA. 30"
HEAD THK. .219 SHELL THK. .250
This container shall not contain a product having a vapor pressure in excess of 250 PSIG at 100 F.
ABOVE GROUND TYPE NO. DS7 WATER CAP. 250 GAL.

Fig. 21 — The Nameplate On LP-Gas Storage Tanks Has Safety Information That Is Important To You

The nameplate also tells whether the tank is designed for aboveground or underground use, its working pressure in pounds per square inch, the capacity of the tank, the name of the supplier and other information you need to know.

Aboveground tanks are considered best for farm use because it is easy to find leaks (by use of a soap-suds solution) in case any develop. You should use soap suds to check for leaks at least once each season.

CAUTION: Don't use a flame for detecting leaks. LP-Gas has an odor additive to help you detect it.

With LP-Gas, as with gasoline, the storage tank must be located a safe distance from major buildings or from other fuel storages. Fig. 22 shows the minimum distances as provided by the standards established by the National Board of Fire Underwriters.

You will also need to protect from accidental damage such parts as the hose connections and pipe fittings that extend from the tank and pump, if a pump is used (Fig. 22). (If the liquid level in the storage tank is below the level of the machine tank, a pump is used to make the fuel transfer the same as with other fuels.)

Fill holes and low spots in the vicinity of the storage. Gas that leaks from the tank, or fuel that escapes while filling the machine tank is heavier than air. It will drain into low spots where it will accumulate and become a fire hazard.

Don't touch LP-Gas with your bare hands as it "freezes" and can burn the skin. Wear leather gloves when handling LP-Gas containers.

CONVENIENCE AND COST

After you have figured the safety precautions, then pick a location that will be easiest for refueling your machine and for refilling the storage tank. Allow about 50 feet of space on one side for maneuvering your machines and equipment and for the tank truck to refill the storage tank.

Since an LP-Gas storage tank is rather expensive, you will want to consider your cost carefully. You will need to provide: (1) for enough reserve capacity to carry through periods of heavy use without having your supplier make a special trip and (2) for taking advantage of seasonal discounts or quantity discounts, if the price quotations are low enough during some seasons of the year to justify a large tank investment.

Standard tank sizes are 250, 500, and 1000 gallons (945, 1890, 3785 liters). *LP-Gas tanks should be filled to only 80 percent of their capacity so the usable capacity of these* tanks would be 200, 400 and 800 gallons (755, 1515, 3030 liters), respectively. This extra space is to allow room for expansion of the liquid on hot days without developing dangerous tank pressures.

In figuring the amount of LP-Gas you are likely to use, you can estimate it as being about 25 per cent more than the amount of gasoline you would use in the same machine. In arriving at tank size, don't plan on getting a tank that will require filling more frequently than every 30 days. Allow several days' reserve capacity for seasons of heaviest use.

If you are already using LP-Gas for other purposes, you have some idea as to how long your present tank capacity will take care of these needs. Determine how much this usage is on a monthly basis and add the maximum amount your machines will use. Then add at least 20 to 25 percent extra capacity to set the minimum size tank you should use.

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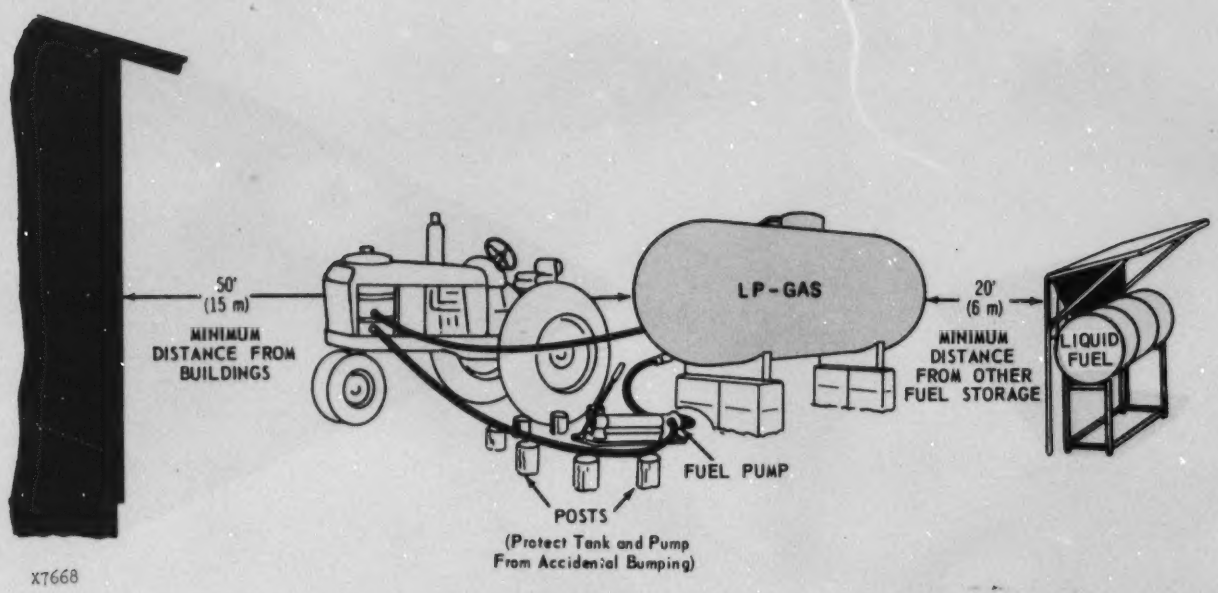

Fig. 22 — Safe Location Of LP-Gas Storage Tanks In Relation To Buildings And Other Fuel Storage

In some areas, where LP-Gas is used for house heating, crop drying, brooding, etc., the cost per gallon is often reduced during the season of least use. You may find it pays to increase the size of tank you install to take advantage of these lower fuel prices if they are available in your area.

Be sure you purchase *both a liquid-fill hose and a vapor-return hose* for your storage tank. When you fill your machine tank with liquid, the vapor from the top of the machine tank should be fed back to the storage tank as a matter of safety (see Fig. 22).

TEST YOURSELF

QUESTIONS

1. Match the types of engines below with the average compression ratios.

a. Gasoline engine	1. 16 to 1
b. Kerosene engine	2. 8 to 1
c. Diesel engine	3. 4 to 1

2. What happens in the cylinder of a gasoline engine during combustion "knock?"

3. Match the three pairs of items below.

a. Gasoline fuel	1. Octane number
b. Diesel fuel	2. Cetane number

A. Must burn FAST
B. Must burn EVENLY

4. Which is more *volatile*, summer gasoline blends or winter blends?

5. True or false? "In diesel engines, knocking is caused by the fuel igniting too fast."

6. Which is more volatile, diesel fuel with a cetane number of 40 or 60?

7. For gasoline fuel storage tanks that must be exposed to sunlight, which is the best color — grey, white, or red?

8. An aboveground gasoline storage tank should be placed at least how many feet from the closest building?

a. 12 ft. (3.6 m)
b. 40 ft. (12 m)
c. 65 ft. (20 m)

9. LP-Gas storage tanks should be filled to what percent of their capacity?

a. 80%
b. 90%
c. 95%

(Answers on page 68.)

LUBRICANTS / PART 2

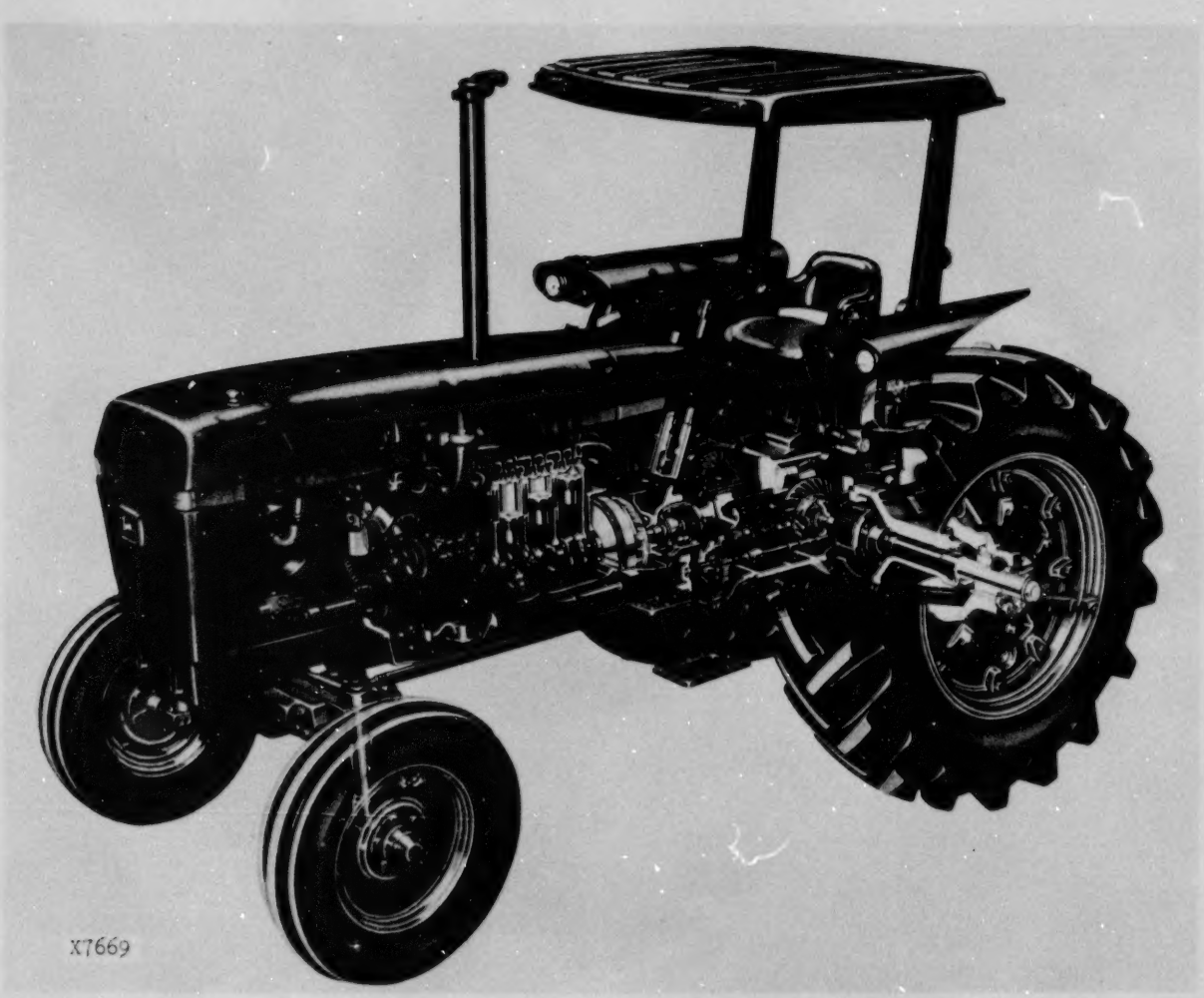

Fig. 23 — Lubrication Protects the Precision Parts of the Modern Tractor

INTRODUCTION

Before modern machines, lubricants had but one purpose: To reduce friction and keep down wear between moving parts.

Selecting a lubricant was no particular problem; it was largely a matter of getting one heavy enough to maintain an effective film between the two contacting surfaces — one that would last from several hours to several weeks, depending on use.

As machines came into general use, the whole lubrication picture changed. The change has been particularly fast since 1940. The reason: Loads are becoming heavier, speeds are faster, and moving parts fit much more closely than in earlier machines.

As a result, lubricants are constantly being changed and improved. As improvements are made, new terms are used such as "additives," "multi-viscosity," etc.

In the discussion that follows, we will explain terms so you can better understand lubricants.

We will cover this information under the following headings:

1. **Engine Oils**
2. **Gear Oils**
3. **Hydraulic and Transmission Fluids**
4. **Lubricating Greases**

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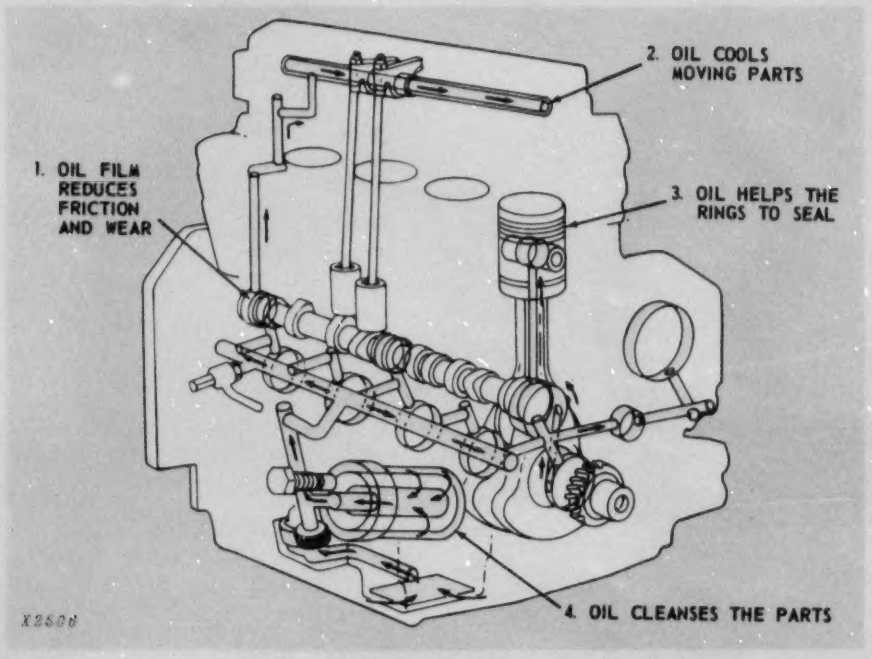

Fig. 24 — —What An Engine Oil Must Do

ENGINE OILS

Once engine lubrication could be done by anyone with an oil can and a single oil. Most oil was supplied in three grades — light, medium, and heavy.

But in today's high-speed engines, all this has changed. Everything is higher — compression, speeds, and temperatures.

Special oils have been developed for each type of engine, for each type of machine, and for each season.

As a result, lubrication has changed from a simple chore to a science of preventive maintenance.

WHAT ENGINE OILS MUST DO

Engine oils have several functions (Fig. 24). Here are four of the most important:

1. Oil Reduces Friction and Wear

Scuffing and scoring is caused by metal-to-metal contact of moving parts. Wear also results from acid corrosion, rusting, and from the abrasion of contaminants carried in the oil.

To prevent metal-to-metal contact, the oil must maintain enough viscosity or thickness to provide a film or cushion between the moving parts under all operating temperatures. In spite of high internal heat, the viscosity must be no higher than necessary to give good starting and yet provide the least friction under sustained running.

2. Oil Cools Moving Parts

Engine oil is largely responsible for piston cooling. This is done by direct heat transfer through the oil film to the cylinder walls and on to the cooling system and by carrying heat from the underside of the piston crown and skirt to the engine crankcase.

Oils of equal viscosities have the same heat conductivity, but the oil must have enough heat stability to resist decomposition when in contact with these surfaces.

3. Oil Helps Seal The Cylinders

During combustion, pressures in the cylinder may be 1000 psi or higher. Oil helps the piston rings to seal these pressures in the cylinder by forming an oil film on the piston and cylinder walls.

4. Oil Keeps The Parts Clean

Contrary to popular opinion, engine oils do "wear out." Extended service not only depletes the additives, but also oxidizes the base oils to harmful compounds. While good filtration will prolong oil life, many contaminants are soluble in the oil and will pass through the filter. These contaminants are primarily unburned or partially unburned fuel, but corrosive acids and water are frequently present.

The oil must prevent the formation of these materials or, once formed, keep them in suspension so they do not settle inside the engine.

If an engine oil is to fulfill all these requirements, the oil must do the following:

1. *Keep a protective oil film on moving parts.*
2. *Resist high temperatures.*
3. *Resist corrosion and rusting.*
4. *Prevent ring sticking.*
5. *Prevent sludge formation.*
6. *Flow easily at low temperatures.*
7. *Resist foaming.*
8. *Resist breakdown after prolonged use.*

If we are to understand fully how engine oils perform their job and the differences between them, it is helpful to know how oils are produced.

PRODUCING TODAY'S ENGINE OILS

Today, in the United States alone, there are more than 300 oil refineries actively engaged in converting crude oil into gasoline, kerosene, fuel oils, lubricants and hundreds of other by-products. These refineries vary in size from those that process 150 barrels of crude oil a day to those that refine up to 160,000 barrels daily.

To understand better the differences in lubricating oils, let's take a look at one of these refineries and learn how petroleum or crude oil is converted to the specialized engine oils of today.

Crude oil is composed of thousands of different combinations of hydrogen and carbon called hydrocarbons. Crude oil, as it comes from the ground, also contains oxygen and traces of nitrogen and sulfur; sometimes clay, water, resins and mineral salts are present.

The various combinations of hydrogen and carbon give special characteristics to the "fractions" or parts of petroleum. Some of these fractions are valuable in themselves, such as natural gas, gasoline, and kerosene. Others must be changed through refining before they can be used. Separating these fractions and converting them to useful products are the two chief jobs of an oil refinery.

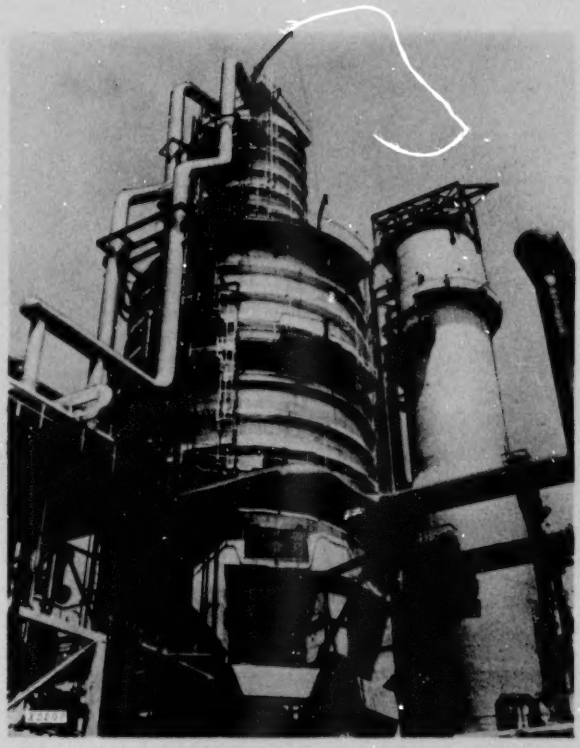

Fig. 25 — Distillation Plant For Distilling Crude Oil

The key step in the refining process is **distillation** or "fractionation." It is by this process that the various parts of crude oil are separated from each other (Fig. 26).

Gases are removed from the top of the distillation tower. Light distillates such as gasoline are removed next, followed by middle distillates such as kerosene, light fuel oil, and diesel fuel oil.

Heavy fuel oils and lubricating oil base stocks are removed from the lower section of the tower. These heavier oils, often referred to as Reduced Crude Oil, are then further refined in the lube oil distillation columns, where steam and vacuum are provided to make distillation possible at a lower temperature.

In the lubricating oil still, the distilled lubricating oil base stock containing wax (but void of all asphalts) is removed from the top of the tower. This stock is further improved and refined by removal of wax, sulfur, sludge and other unwanted materials.

The lubricating oil base stocks are then blended to various viscosities. Additives are introduced into the oil to make it flow more freely at low temperatures, to protect engine parts from rust and corrosion, and to give the oil special properties to adapt it to its special use.

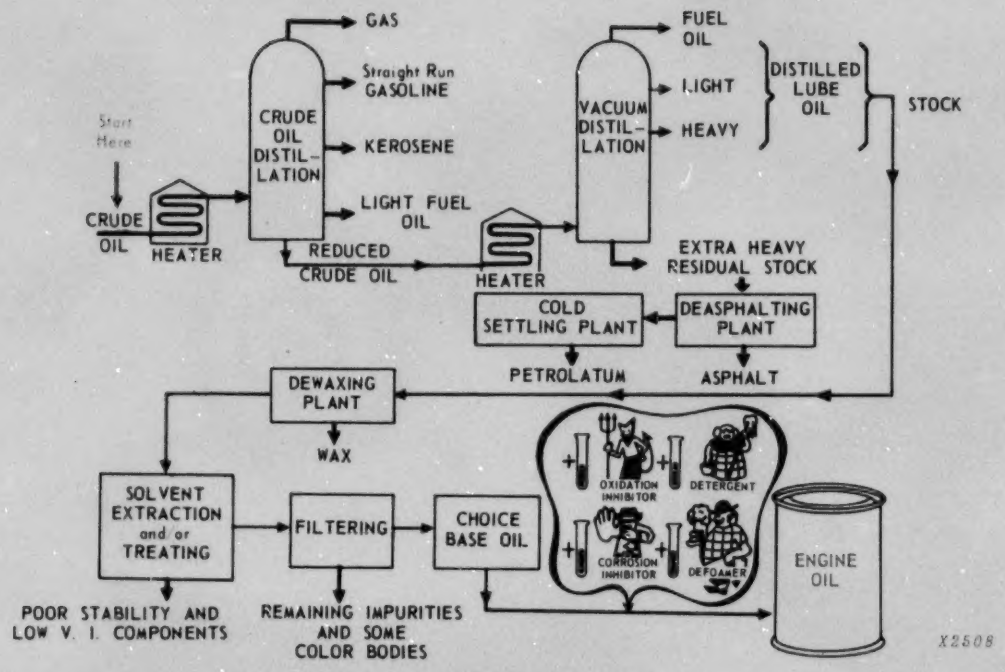

Fig. 26 — Lubricating Oil Refining Process

ENGINE OIL RATINGS AND CLASSIFICATIONS

If you are to receive the best performance possible from a machine, it is important to use lubricants of highest quality. The savings to be gained with lower-quality lubricating oil are at best small in relation to the over-all operating costs.

The apparent savings with cheap, inferior lubricating oils will be more than wiped out over the long run due to reduced output and greater maintenance costs. Therefore, be sure to use brands and grades of recognized quality . . . and deal only with suppliers having a reputation for dependability and the necessary technical skill to serve their needs.

How can you be assured of obtaining an oil of high quality and one that's right for the job? First, choose oil from a reliable supplier — a reputable brand of oil. Then use the type of oil that's recommended for the equipment.

Several classifications of oil have been set up. These include:

(1) The SAE Viscosity established by the Society of Automotive Engineers.

(2) API Service Classification established by the American Petroleum Institute.

(3) MIL Specification prepared by the Ordnance Department of the U.S. Army, Navy and Air Force.

(4) Manufacturer's Specifications developed by some engine makers.

(5) ASTM Engine Sequence Tests whose procedures are adopted by the American Society for Testing Materials.

Let's take a look at each of these rating systems.

Fig. 27 —— Confused About Oil Ratings?

SAE VISCOSITY

Oil **viscosity** is a measure of the fluidity of an oil at a given temperature. The lighter or more fluid oils intended for winter use are specified at 0°F (−18°C) and carry a 5W, 10W or 20W symbol. Heavier oils are specified at 210°F (99°C).

In the viscosity test, a measured quantity of the oil is brought to the specified temperature (usually 100 F or 210 F) (38 C or 99 C). The length of time in seconds required for a specified volume of oil to flow through a small orifice in an instrument such as a Saybolt or Kinematic Viscometer is recorded (Fig. 28). The SAE grade is determined by referring to the SAE (Society of Automotive Engineers) Chart (shown at right).

SAE CRANKCASE OIL CLASSIFICATION

SAE Viscosity Number	Time of Flow Through Saybolt Viscometer in Seconds			
	at 0 F (−18 C)		at 210 F (99 C)	
	Min.	Max.	Min.	Max.
5W	—	6,000	—	—
10W	6,000 (Note A)	less than 12,000	—	—
20W	12,000 (Note B)	48,000	—	—
20	—	—	45	less than 58
30	—	—	58	less than 70
40	—	—	70	less than 85
50	—	—	85	110

Note A. Minimum viscosity at 0°F may be waived provided viscosity at 210°F is not below 40 seconds, Saybolt Universal.
Note B. Minimum viscosity at 0°F may be waived provided viscosity at 210°F is not below 45 seconds, Saybolt Universal.

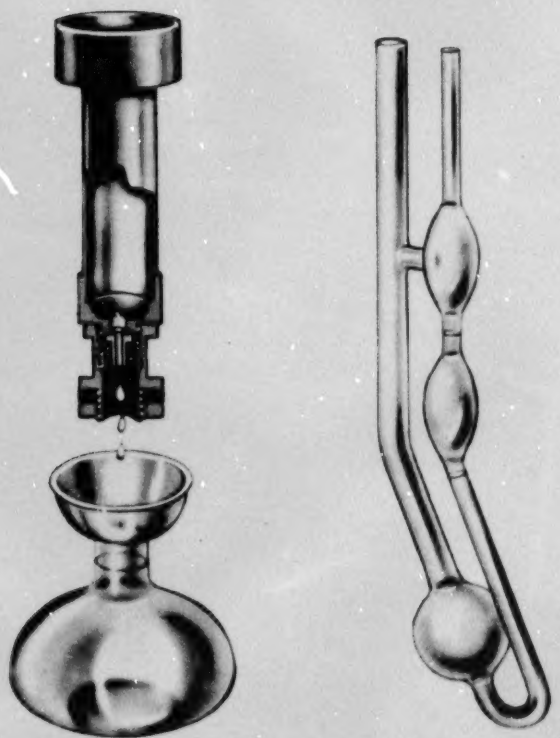

Fig. 28 — Saybolt Viscometer (Left) and Kinematic Viscometer (Right)

Oils vary in viscosity as temperatures change — becoming more fluid as temperatures increase and less fluid as temperatures decrease. The temperature effect on viscosity is not the same for all oils, and a measure of this is often important to the user.

Some oils are compounded to behave as light oils at cold temperatures, and as heavier oils at high temperatures. These oils are called **multi-grade** or **multi-viscosity** oils and include, for example 10W-30 (Fig. 29). Where recommended, one multi-viscosity oil can replace as many as four or five single-grade oils.

Multi-viscosity oils can give protection at both high and low temperatures. However, multi-viscosity oils are primarily intended for use during seasons in which both extreme cold and warm periods occur. They are *not* usually recommended for use in warm weather in medium to heavy-duty applications.

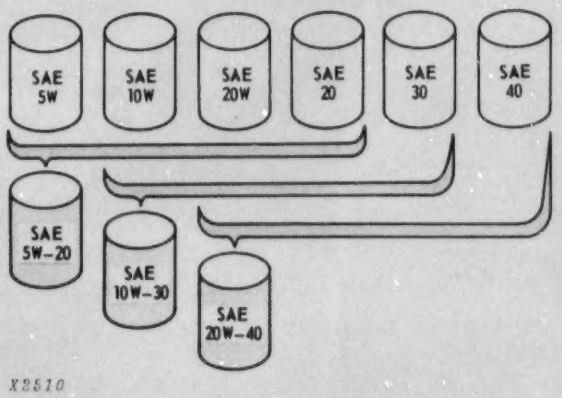

Fig. 29 — —A Multi-Viscosity Oil Can Replace Several Single-Viscosity Oils (When Recommended)

Fig. 30 — Oil Viscosity Is Marked On Oil Containers

SAE viscosity numbers are widely used as a means of identifying and classifying lubricating oil, and today are found on practically all cans or drums of oil marketed in the United States (Fig. 30).

Each number indicates a permissable range or limit of viscosity at specified temperatures.

No attempt is made to define the oil's quality, additive content, performance value or suitability for specified service conditions.

Therefore, the SAE viscosity should not be the only factor considered when selecting an oil.

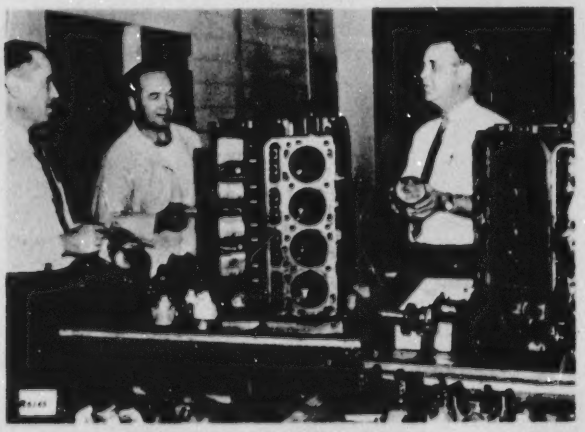

Fig. 31 — Research Scientists Examine Engine Parts After API Service Tests

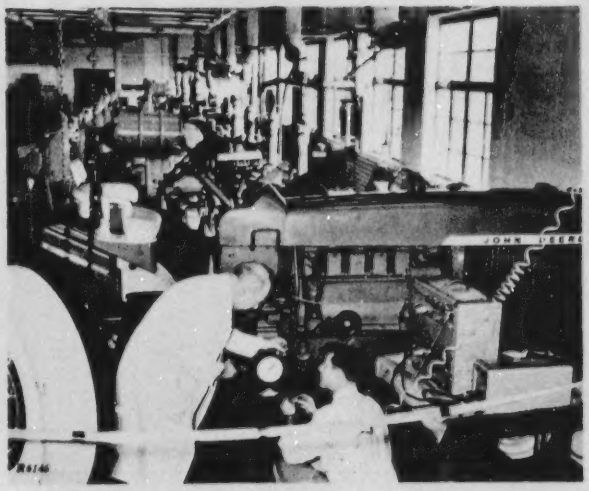

Fig. 32 — Modern Test Laboratory For Engine Oil Tests

API SERVICE DESIGNATIONS

The new API classification system was a joint effort of the API, ASTM, and SAE organizations. It attempts to clarify the oil specifications and better define oil qualities between the engine manufacturer, the petroleum industry, and the customer.

Often on farms and on certain types of construction jobs where diesel-powered equipment is operated along with gasoline-powered equipment, operators may wish to lubricate all of their equipment with the same type of oil. In such cases, a diesel engine oil that can also be used in gasoline engines may be desired. Lubricants meeting more than one classification can be so marked. Some oils, therefore, are designated "For Service CD/SD" or "For Service CC/SE."

API oil classifications are shown in the charts on the following two pages.

FOS — 58 Litho in U.S.A.

API SERVICE RATINGS FOR ENGINE OILS

SAE Letter Designation	API Brief Identification and Engine Service Description	ASTM Engine Oil Description
SA	*Utility Gasoline & Diesel Engine Service* Service typical of engines operated under such mild conditions that the protection afforded by compounded oils is not required. This classification has no performance requirements.	Oil without additive except that it may contain pour and/or foam depressants.
SB	*Minimum Duty Gasoline Engine Service* Service typical of engines operated under such mild conditions that only minimum protection afforded by compounding is desired. Oils designed for this service have been used since the 1930's and provide only anti-scuff capability, and resistance to oil oxidation and bearing corrosion.	Provides some anti-oxidant and anti-scuff capabilities.
SC	*1964 Gasoline Engine Warranty Service* Service typical of gasoline engines in 1964 through 1967 models of passenger cars and trucks operating under engine manufacturers' warranties in effect during those model years. Oils designed for this service provide control of high and low temperature deposits, wear, rust and corrosion in gasoline engines.	Oil meeting the 1964-1967 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides low temperature anti-sludge and anti-rust performance.
SD	*1968 Gasoline Engine Warranty Service* Service typical of gasoline engines in passenger cars and trucks (1968 through 1970 models) and operating under engine manufacturers' warranties. Oils designed for this service provide more protection from high and low temperature engine deposits, wear, rust and corrosion in gasoline engines than oils for API Service Classification SC and may be used when oils for API Service Classification SC are recommended.	Oil meeting the 1968-1971 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides low temperature anti-sludge and anti-rust performance.
SE	*1972 Gasoline Engine Warranty Service* Service typical of gasoline engines in passenger cars and trucks beginning with 1972 and certain 1971 models and operating under engine manufacturer's warranties. Oils designed for this service provide more protection against oil oxidation, high-temperature engine deposits, rust and corrosion than SC or SD and may be used when oils for API Gasoline Engine Warranty Maintenance Classification SC or SD are recommended.	Oil meeting the 1972 requirements of the automobile manufacturers. Intended primarily for use in passenger cars. Provides high-temperature anti-oxidation, low-temperature anti-sludge and anti-rust performance.

(Continued on page 34)

API SERVICE RATINGS FOR ENGINE OILS — Continued

SAE Letter Designation	API Brief Identification and Engine Service Description	ASTM Engine Oil Description
CA	*Light Duty Diesel Engine Service* Service typical of diesel engines operated in mild to moderate duty with high quality fuels. Occasionally has included gasoline engines in mild service. Oils designed for this service were widely used in the late 1940's and 1950's. These oils provide protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines when using fuels of such quality that they impose no unusual requirements for wear and deposit protection.	Oil meeting the requirements of MIL-L-2104A. For use in gasoline and naturally aspirated diesel engines operated on low sulphur fuel. The MIL-L-2104A Specification was issued in 1954.
CB	*Moderate Duty Diesel Engine Service* Service typical of diesel engines operated in mild to moderate duty, but with lower quality fuels which necessitate more protection from wear and deposits. Occasionally has included gasoline engines in mild service. Oils designed for this service were introduced in 1949. Such oils provide necessary protection from bearing corrosion and from high temperature deposits in normally aspirated diesel engines with higher sulfur fuels.	Oil for use in gasoline and naturally aspirated diesel engines. Includes MIL-L-2104A oils where the diesel engine test was run using high sulfur fuel.
CC	*Moderate Duty Diesel & Gasoline Engine Service* Service typical of lightly supercharged diesel engines operated in moderate to severe duty and has included certain heavy-duty, gasoline engines. Oils designed for this service were introduced in 1961 and used in many trucks and in industrial and construction equipment and farm tractors. These oils provide protection from high temperature deposits in lightly supercharged diesels and also from rust, corrosion and low temperature deposits in gasoline engines.	Oil meeting requirements of MIL-L-2104B. Provides low temperature anti-sludge, anti-rust and lightly supercharged diesel engine performance. The MIL-L-2104B specification was issued in 1964.
CD	*Severe Duty Diesel Engine Service* Service typical of supercharged diesel engines in high-speed, high-output duty requiring highly effective control of wear and deposits. Oils designed for this service were introduced in 1955, and provide protection from bearing corrosion and from high temperature deposits in supercharged diesel engines when using fuels of a wide quality range.	Oil meeting the requirements of the Caterpillar Tractor Co. Series 3 specification. Provides moderately supercharged diesel engine performance. The Series 3 specification was established by Caterpillar in 1955. The related MIL-L-45199 specification was issued in 1958.

SUMMARY: API RATINGS OF ENGINE OILS

The tables above include all engine oils currently marketed in volume for use in passenger cars, gasoline- and diesel-powered trucks and gasoline- and diesel-powered off-highway equipment.
However, some of the classifications may not currently be recommended by manufacturers for use in their own equipment. A general cross-reference of current recommendations, current common names, and new Performance Classifications is given below.

SUMMARY OF CURRENT EQUIPMENT MANUFACTURER RECOMENDATIONS

Application	Oil Recommendations		Comments
	API Performance Classification	Current Common Name	
Gasoline Engine, Passenger Car	SE[1]	——	Meets warranty requirements of passenger car manufacturers.
Gasoline Engine, Truck and Bus	CC SE[1]	MIL-B ——	Principally concerned with heavy duty, some applications may require improved low temperature performance of SE.
Diesel Engine, Truck and Bus	CB CC CD[2]	Supplement 1 MIL-B Series 3 (S-3)	Recommendation of performance level involves consideration of engine design factors as well as application.
Diesel Engine, Off Highway	CB CC CD[2]	Supplement 1 MIL-B Series 3 (S-3)	Recommendation of performance level involves consideration of engine design factors as well as application.

1. Oils meeting the performance requirements of MIL-L-46152 meet or exceed the performance requirements of both SE and CC.
2. Oils meeting the performance requirements of MIL-L-2104C meet or exceed the performance requirements of both CD and SC.

MILITARY (MIL) AND ENGINE MAKER'S SPECIFICATIONS

During the 1930's, the Caterpillar Tractor Company pioneered in the development of engine tests to evaluate the performance properties of diesel engine oils.

Ring-sticking and ring and cylinder-scratching problems became epidemic and, through cooperation with several oil companies, the first additive oil was made available commercially in 1935.

About 1938, the oil industry began developing oils to meet the needs of General Motors Detroit Diesel Division's new high-speed diesel engines. This added another line of oils, resulting in a double inventory for diesel engines.

In 1941, the Military began qualifying engine oils.

The U.S. Army 2-104 specification was issued to cover oils meeting both Caterpillar and General Motors requirements. In 1943 the Ordnance Reviewing Committee was organized and included representatives from Caterpillar, General Motors, Armour Research Foundation and Army Ordnance. The diesel engine oil evaluation tests then included:

CRC L-1 — Caterpillar 1-A endurance test (single cylinder)

CRC L-2 — Caterpillar scratch test (single cylinder)

CRC L-3 — Caterpillar "hot box" bearing corrosion test (four cylinder)

CRC L-4 — GM Chevrolet oxidation stability and bearing corrosion test (gasoline — six cylinder)

CRC L-5 — GM 71 endurance test (2 cycle — three cylinder)

After World War II, the L-2, L-3 and L-5 tests were dropped as it was found that the L-1 and L-4 were adequate to evaluate diesel engine oils.

Caterpillar engine tests have continued to be the backbone of any diesel engine oil evaluation program. These diesel single-cylinder engine test procedures have been progressively modified to meet changes in engine design (increased BMEP, speed and temperatures, supercharging, etc.) and operating conditions (continuous high-load earthmoving to stop-and-go delivery service). These tests primarily evaluate the effect of engine oil on ring sticking and piston deposition.

The Military continued to include these Caterpillar tests in their diesel engine oil specifications leading to engine oil approvals. The military engine oil specifications have been progressively revised to reflect the engine oil performance criteria demanded to meet new engine design and operating condition requirements.

The military specifications included additional gasoline engine tests to evaluate the effect of engine oil quality on bearing corrosion, engine wear, and engine deposition (rust, sludge and varnish).

The various MIL specifications are shown in the chart below. Older ratings are shown in the left column, while more current ones are shown on the right.

SUMMARY OF MILITARY (MIL) AND ENGINE MAKER'S SPECIFICATIONS FOR ENGINE OILS

Specification	Description	Specification	Description
MIL-L-2104A (Obsolete)	Oil meeting minimum requirements of MIL-L-2104A. For use in gasoline and naturally aspirated diesel engines operated on low sulfur fuel. MIL-L-2104A Spec. was issued in 1954 and superseded by MIL-L-2104B.	**MIL-L-46152 (Current)**	This specification describes engine oils suitable for gasoline engines in farm tractor and passenger car service. It also describes oils for diesel engines in light to moderate service where Series 3 performance is not required. It provides more low-temperature sludge and rust protection for gas and diesel engines than MIL-L-2104C (below).
Supplement 1 (Obsolete)	Oil for use in gasoline and naturally aspirated diesel engines, Includes MIL-L-2104A oils where diesel engine test was run using high sulfur fuel.	**MIL-L-2104C (Current)**	This specification describes engine oils with Series 3 diesel engine performance for moderate to heavy-duty diesel engines, including those using high-sulfur fuels. Low-temperature sludge and rust performance in gas and diesel engines is also required, but at a lower level than is required for MIL-L-46152 (above).
Series 3 (Current) and MIL-L-45199 (Obsolete)	Oil meeting minimum requirements of Caterpillar Tractor Co. provides moderately supercharged diesel engine performance. Series 3 specification was established by Caterpillar in 1955. Related MIL-L-45199 Spec. was issued in 1958.		
MIL-L-2104B (Obsolete)	Oil meeting minimum requirements of MIL-L-2104B. Provides low temperature sludge anti-rust, and lightly supercharged diesel engine performance. MIL-L-2104B Spec. was issued in 1964.		

These engine oil specifications should be used only as a yardstick for helping to assure products are suited for the purpose intended. They should not be used to tell the optimum or ultimate in performance. These specifications describe products which will work with a reasonable degree of satisfaction for a given requirement, but they do not necessarily indicate that the product is the best quality oil or the least expensive available.

Although military specifications do not govern non-military uses for engine oils, many non-military users request oils which have qualified under these requirements, because such oils have had successful performance records. For this reason, oil manufacturers often identify their containers with the MIL specification.

Today many machine makers have gone beyond the above standards and have developed their own specific oils. An example is "Torq-Gard" developed specifically for John Deere engines. This oil has been formulated for off-the-road operation as opposed to road driving and gives added advantages not offered by automotive engine oils.

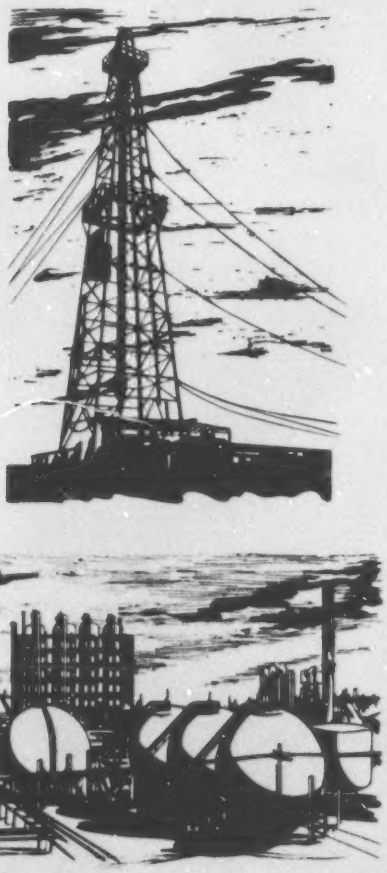

Fig. 33 — Engine Oils Are Highly Refined Petroleum

CONTAMINATION OF OIL

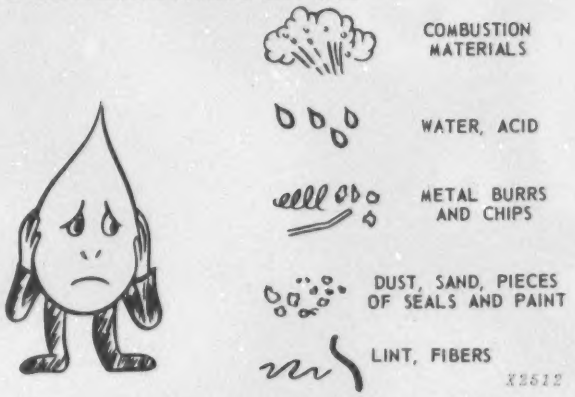

Fig. 34 — Contamination Of Oil

Most people — even many servicemen — are still not fully aware of the harmful effect of **contaminants** on an engine oil's performance. Contaminants seriously hamper good lubrication, regardless of the oil's original quality.

Engine oil quality is probably being stressed more today than ever before, but the effect of oil contaminants many times hinders engine performance even more than using a poor quality oil. As a matter of fact, contaminants that collect in oil under normal operating conditions, to say nothing of adverse conditions, can reduce engine life more than any other single factor.

Let's take a look at some of the many oil contaminants, how they enter the engine, what oil companies are doing to counteract them and what you can do.

FOREIGN PARTICLES IN OIL

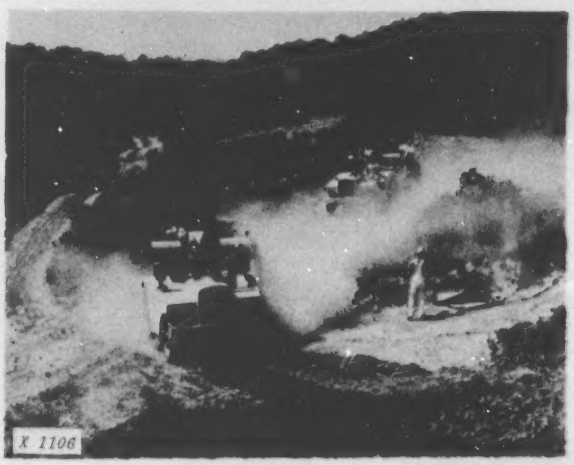

Fig. 35 — Dust Is A Major Source Of Oil Contamination

Probably the most familiar of the external contaminants is dust breathed in with the combustion air (Fig. 35).

Similar material also enters the engine crankcase directly as a result of the breathing action taking place there.

In diesels, fuel soot particles from combustion enter the crankcase oil with blowby gases.

Microscopic metal particles also get into the oil as a result of normal engine wear.

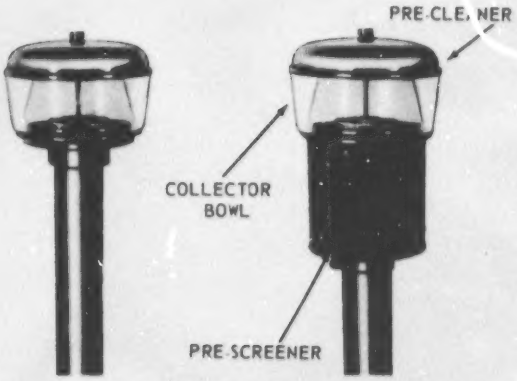

Fig. 36 — Pre-cleaners And Pre-Screeners Keep Large Foreign Particles From Reaching The Air Cleaner

As these foreign particles accumulate, increased wear soon results in the cylinder bore, on piston rings, and within bearings, even though the best oil was used originally. Early engine failure may result.

These tiny particles also restrict oil flow, and in combination with water and oxidized products, form sludge. Metal particles accelerate wear and damage bearings. Fuel soot thickens the oil and interfers with lubrication.

Oil companies have helped in the fight against these contaminants by introducing additives into the oil. **Anti-scuff** additives help reduce the number of metal particles resulting from engine wear. **Detergents** reduce deposit build-up. **Dispersants** keep contaminants finely dispersed in the oil, thus not interfering with the lubricating qualities of the oil. This also permits particles to drain out with the oil.

Machine operators can help also in preventing early engine failure through proper care of the air cleaner (Fig. 37), oil filler breather cap, and crankcase ventilator . . . through regular and frequent oil and oil filter changes . . . and by proper storage and handling of lubricants.

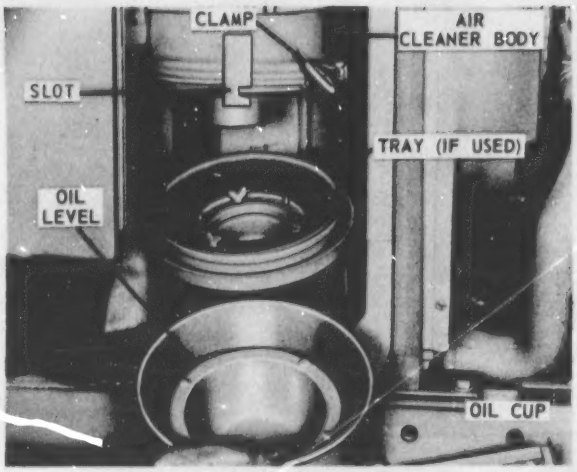

Fig. 37 — Regular Air Cleaner Service Helps Prevent Costly Engine Damage

Lubricants should be stored in clean, closed cabinets or rooms; covers and pourspouts on the drums or containers should be kept closed when not in use. This not only keeps out impurities, but it also reduces condensation of water caused by atmospheric changes. This will be covered later under "Storage and Handling."

WATER CONTAMINATION OF OIL

Water vapor, a normal product of combustion, tends to condense and collect as water in the crankcase during periods of cold engine operation. Each gallon of fuel consumed produces more than a gallon of water. This water, which is not completely vaporized until the cylinder wall temperature reaches 145°F (63°C), condenses on colder cylinder walls and is scraped down into the crankcase oil.

Water is a trouble-maker which causes rusting of vital steel and iron surfaces. Eight times as much engine or cylinder wear occurs in an engine operating at 100°F (38°C) than at 160°F (71°C).

Fig. 38 — Ice In Crankcase Following Cold Engine Operation

Water in the crankcase may freeze (Fig. 38) or it may combine with oxidized oil and carbon to form cold-engine sludge. Sludge can plug oil screens and often collects in piston oil ring grooves, interfering with ring action. Oil line plugging also occurs at times. Rust, which may result from water, further contaminates the oil.

Oil companies have introduced special rust inhibitors into oils. These inhibitors aid in protecting precision parts. Detergent-dispersants keep parts clean and deposits in suspension, helping to prevent sludge.

You can help prevent severe engine damage by:

(1) Warming up engine properly before a load is applied.

(2) Making sure engines are brought up to normal operating temperatures each time they are used.

(3) Using proper thermostats to heat engines to correct temperatures as quickly as possible.

(4) Checking engine temperatures frequently.

(5) Draining crankcase oil while engine is warm.

ANTIFREEZE CONTAMINATION OF OIL

Proper cooling system maintenance will prevent contamination of engine oil by antifreeze.

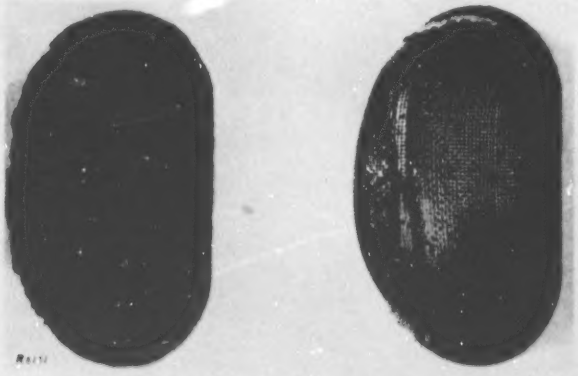

Fig. 39 — Antifreeze In Crankcase Results In Sludge Formation And Can Clog Oil Screens

Antifreeze will oxidize in oil, forming sludge or gummy, resinous products (Fig. 39). It also tends to strip out other oil additives so they no longer give protection. This results in a varnish build-up on bearings. Sludge forms on the oil screen, oil pan and in push rod chambers, while rust forms on the valve train. Antifreeze contamination usually results in the need for a complete engine overhaul. Special precautions can be taken against antifreeze contamination by:

(1) Following specified service manual procedures when torquing head bolts during overhaul (NOTE: Be sure to retorque bolts, when specified).

(2) Using a cooling system sealer prior to filling with permanent antifreeze.

(3) Removing antifreeze as soon as the danger of freezing passes and servicing the engine with a summer coolant conditioner.

(4) Guarding against incorrect timing and improper use of starting fluids in diesel engines, both of which can result in head gasket damage.

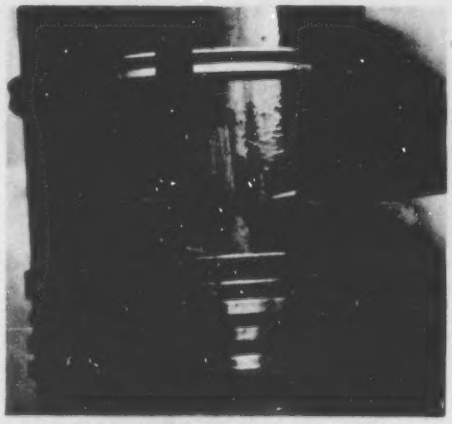

Fig. 40 — Varnish Build-up On Pistons

FUEL CONTAMINATION OF OIL

In **gasoline engines**, overchoking, engine missing, carburetor flooding, and cold engine operation all tend to let gasoline seep into the oil. This raw fuel runs down the cylinder walls, past the rings, washing away the lubricating oil and increasing engine wear.

In **diesel engines**, fuel contamination of oil may be caused by a cracked fuel pump diaphragm or by a leak in the fuel injection pump shaft seal. Piston seizure and short bearing life can result in diesel engines if crankcase dilution is excessive.

In both types of engines (diesel and gasoline), the partially oxidized fuel and the unburned fuel which mix with oil in crankcase contribute to deposits forming in engines in general and on piston surfaces (as varnish) in particular.

Deposits on pistons cause rings to stick (Fig. 40), and accelerated engine failure usually results.

Antioxidants are added to some oils to help halt the chemical processes which result in varnish or acid formation. Detergent-dispersants are added to carry any varnish or deposits out of the ring area and to keep them in suspension until oil is drained.

Machine owners can help prevent fuel contamination of oil by remembering these simple rules:

(1) Don't overchoke an engine.

(2) Never run an engine when it is misfiring.

(3) Avoid too much idling of diesel engines.

(4) Have flooding carburetors repaired.

(5) Keep the diesel fuel system in good operating condition.

(6) Make sure engines are brought up to normal operating temperature each time they are used.

(7) Buy clean-burning fuel.

OVERHEATING OF OIL

High operating temperatures, caused by heavy loads, faulty cooling systems, bad timing, preignition and detonation, speed up oxidation of oils. A rule of thumb: Every 18-degree increase in temperature above 185 F (85 C) **doubles** the oxidation rate of average oil.

Oxidation breaks down the oil and forms deposits. This results in ring sticking, valve sticking and sludge. The antioxidants, mentioned above, help protect the oil from oxidation and reduce oil breakdown.

You can help prevent engine damage from oxidation due to high operating temperatures by making sure the cooling system is properly maintained and that temperature gauges are working properly. Check the engine temperature frequently . . . have engine timing checked periodically (Fig. 41) . . . and use proper fuel as recommended in the operator's manual. To get better engine performance and less overheating, avoid over-working the engine.

OXIDATION OF OIL

Oil deteriorates in use through changes in its nature and composition, mainly caused by oxidation. The conditions under which oil is used in an engine are very conducive to this reaction.

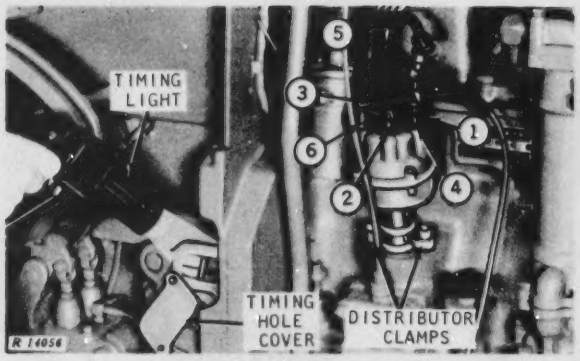

Fig. 41 — Have The Engine Tuned As Outlined In The Operator's Manual

In the crankcase, oil is sprayed from the various moving parts, forming a mist of oil particles in intimate contact with air and at a fairly high temperature.

In the combustion chamber, the oil is also present partly as a mist, being scraped up the cylinder walls at very high speeds by the rising piston, and is at a much higher temperature.

Oxidation products are formed in the oil; their nature depends largely on the temperature.

In the crankcase, oxidation produces acids and also the complex carbonaceous products known as "asphaltenes." These materials in combination with fuel contaminants, assist in forming the stable sludge which is particularly related to low temperature operation.

In the combustion chamber, oil forms a so-called carbon deposit by a combination of oxidation and decomposition by heat. Part of this deposit is washed back to the sump while part remains in the combustion space.

The effects of oxidation will thus aggravate the condition of the oil caused by contamination with the combustion products. The result will be an oil containing acids which may corrode bearing metals and also form resins which may deposit on the pistons and hot metal parts as varnish.

The use of highly refined oils has lessened the risk of oxidation, and further improvement can be obtained by anti-oxidant additives. It is also possible to include either additives to neutralize the acids formed by combustion of the fuel or, alternatively, one additive acting as anti-oxidant and neutralizer. Such additives can greatly improve the performance of engine oils and are used today in most grades.

OIL ADDITIVES

Special oil additives are put into lubricating oils to provide the extra performance required of today's high-speed engines.

Each additive or combination of additives is included in an oil for a specific reason, based on the service expected for that oil.

An oil may contain none, some, or all of the additives described below.

NOTE: Most quality engine oils already contain the needed additives for all conditions where they are recommended. Therefore, most engine manufacturers say, "NEVER PUT ADDITIVES IN THE ENGINE CRANKCASE." The use of crankcase additives may actually reduce oil protection rather than help it.

ANTI-CORROSION ADDITIVE

Helps prevent failure of alloy bearings from corrosive acids which are formed as a normal by-product of combustion. Protects other metal surfaces from corrosive attack. Works with oxidation inhibitor.

OXIDATION INHIBITOR ADDITIVE

Helps keep oil from oxidizing even at high temperatures. Prevents acid, varnish and sludge formations. Protects alloy bearings from corrosion. Prevents oil molecules from combining with oxygen.

ANTI-RUST ADDITIVE

Prevents rusting of metal parts during storage periods, downtime, or even overnight or over weekends. Neutralizes acids so they are no longer harmful. Clings to metal surfaces and builds up a protective coating, which repels water droplets and protects metal from rust.

VISCOSITY INDEX IMPROVER

Helps an oil give top lubricating protection at both low and high temperatures. Multi-grade oils with this additive span an extra-wide range of viscosity grades compared to single grade oils. Lighter oils make starting easier at lower temperatures, but thin out as the oil heats up. Heavier oils give good protection at high temperatures, but become thick and cause hard starting and improper lubrication at low temperatures. A viscosity index improver gives the oil the beneficial properties of both light and heavy oils.

POUR POINT DEPRESSANT ADDITIVE

Prevents wax crystals from congealing in cold weather and forming clumps. (Some paraffin wax is present in lubricating oil, although most wax is removed during refining processes.) These wax crystals tend to congeal in cold weather, interfering with oil flow and causing lubrication difficulties.

EXTREME PRESSURE ADDITIVE

Assures lubrication where extreme pressures between close tolerance and metal-to-metal surfaces are encountered. They reduce friction, prevent galling, scoring, seizure and wear.

DETERGENT-DISPERSANT ADDITIVE

Helps keep metal surfaces clean and prevents deposit formation. Particles of soot and oxidized oil or fuel are kept suspended in the oil. Suspension is so fine that it passes through oil filter and continues to be carried by the oil. Regular drain periods result in the removal of suspended contaminants. Black oil is evidence that an oil is helping keep the engine clean by carrying combustion particles in the oil rather than letting them accumulate on parts as sludge.

FOAM INHIBITOR ADDITIVE

Helps prevent air bubbles which would otherwise restrict lubrication. Speeds up rate at which air bubbles break up, keeping oil from foaming as it circulates rapidly in today's modern, high-speed engines.

MISTAKEN IDEAS ABOUT OILS

Many people hold mistaken ideas about oils. Some of these people learn the hard way — through expensive overhauls; others pay daily for their poor understanding of lubricants. **Let's look at some of these mistaken ideas.**

1. OIL DOESN'T WEAR OUT

Fig. 42 — Always Use New Oil In The Engine Crankcase

This is a mistaken belief of many who feel oil is always slippery and therefore is always effective. Oil loses many of its good lubricating qualities as it absorbs contaminants and as its additives are depleted. Acid formation, sludge and varnish, and engine deposits all tend to cause the oil to become unfit for further use (Fig. 42).

2. MULTI-VISCOSITY OILS ARE PREFERRED

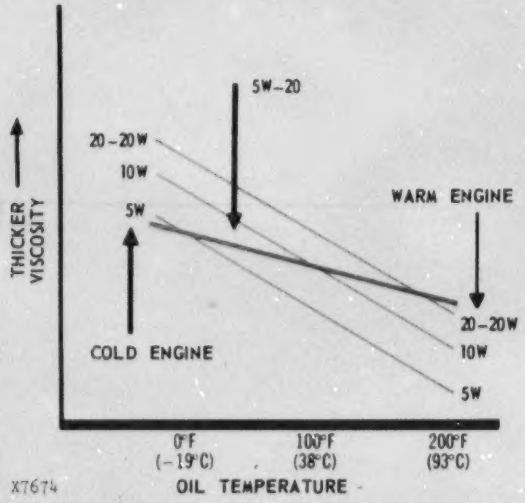

Fig. 43 — Viscosity-Temperature Characteristics Of Multi-Viscosity Engine Oils Compared To Single-Viscosity Oils

While multi-viscosity oils may be required for seasons of both extreme cold and warm weather, a single-viscosity oil is usually recommended for warmer seasons and for heavy-duty engines, especially diesels where cold weather starting is not a problem.

3. BLACK OIL MEANS TIME FOR AN OIL CHANGE

This is not true. For example, in a diesel engine, oil *should* turn black with use to be effective. Detergent and dispersant additives in the oil clean and hold deposits in suspension for removal at the time oil is drained.

4. CHEAP OIL SAVES MONEY

Too many people today are trying to save money on oil, when they should be saving their engines. Ten dollars saved through cheap oils can result in hundreds of dollars of expense through engine repairs.

5. "ANY FILTER WILL DO"

Any filter is better than a clogged filter, but the money saved by buying cheap, "will-fit" filters is negligible compared to the engine damage that

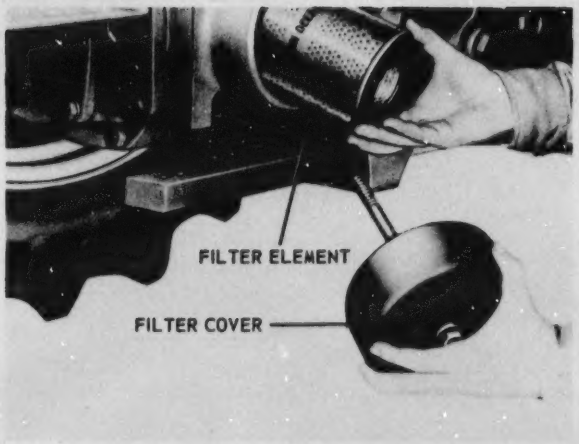

Fig. 44 — Use Genuine Oil Filters For Replacement

can possibly result from their use. Some filters are so dense that not enough oil will pass through. This causes most of the oil to bypass the filter. Others, however, permit damaging contaminants to pass through. Buy quality oil filters as recommended in your machine operator's manual (Fig. 44).

6. OIL OXIDATION RESULTS IN THINNER OIL

This is wrong. Oil oxidation results in **thicker** oil. A viscosity increase indicates that either an oil is breaking down or it is badly contaminated. On the other hand, two things cause thinning of oil — high temperatures and dilution by fuel.

7. LIGHT OILS ARE BEST UNTIL CONSUMPTION RISES

Many operators like to use a light oil as long as they can, and switch to heavier oils as oil consumption increases. This is not the best practice to follow. Use the chart in your operator's manual to insure use of the correct oil.

8. "OPERATOR'S MANUAL RECOMMENDATIONS ARE NOT THAT CRITICAL"

Many owners pay far too little attention to their operator's manuals. Lubrication recommendations in these manuals are there to insure good performance over a long period of time. Refer to the operator's manuals and follow the recommended lubrication practices.

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Fig. 45 — Read Your Operator's Manual And Use It As A Service Reminder

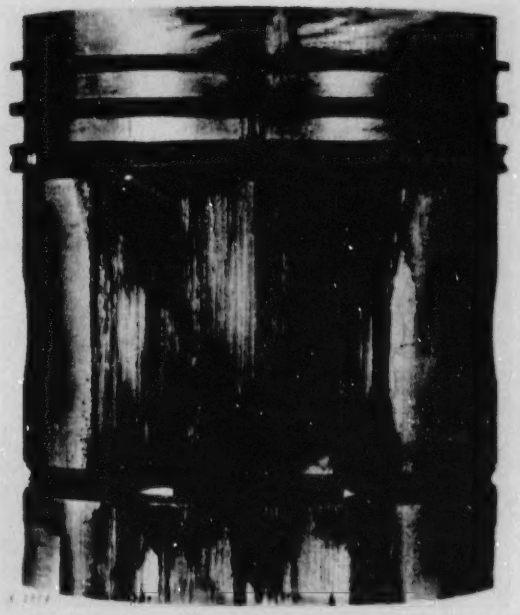


Fig. 46 — Scored Piston (Due To Loss Of Oil Film)

SPECIAL OILS FOR OFF-THE-ROAD MACHINES

With the development of modern high-compression, high-speed engines with very close tolerances, it became apparent to some engine manufacturers that modern day oils did not fully satisfy the requirements of some engines.

Most modern oils were compounded basically to satisfy a wide range of requirements — automobile, truck, tractors, industrial, and aviation engines.

They had to withstand, particularly with automobiles and trucks, a great deal of stop-and-go operation and at the same time perform satisfactorily under continuous, full-load operation as in farm and industrial machine operation.

Initially, automobile and truck oil change recommendations were at 1000 mile (1600 kilometers) intervals. Later the recommendation was changed to 3000 mile (4800 kilometers) intervals or every 60 days, whichever occurred first.

Under the best operating conditions, which would be continuous day-by-day driving at an average speed of 50 miles per hour (80 k/hr), 3000 miles (4800 kilometers) of driving would take 60 hours. Stop-and-go, excessive idling, and cold engine operation imposed greater demands for a high-quality oil.

Farm and industrial machines, however, present a different picture. They normally operate continuously under full load, at a constant speed, over relatively long periods of time, with a minimum of stop-and-go operation. Oil change periods vary from 100 to 250 hours of operation.

Compared to automobile and truck operation, it is obvious that farm and industrial machine engines present a much different lubrication problem.

For example, automobile and truck oil changes are recommended after 3000 miles (4800 kilometers) of travel or about 60 hours at an average of 50 miles per hour (80 k/hr). Farm and industrial engine oil changes are typically recommended every 100-250 hours of operation. Converted to miles traveled at 50 miles per hour (80 k/hr), every 100 hours would represent **5000 miles (8000 kilometer)** of automotive travel.

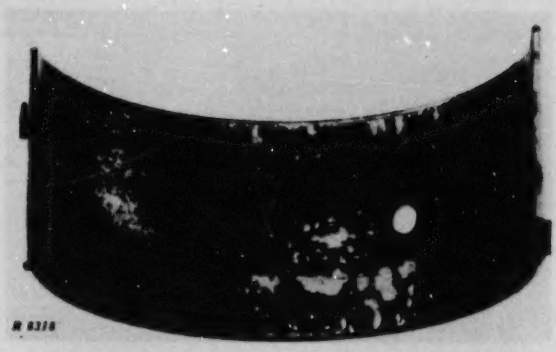
While it is true that the automotive engine is subjected to much more stop-and-go, idling, and cold engine operation, it is seldom subjected to extended, full-load operation.

The farm and industrial engine has the advantage of less stop-and-go operation and of operating most of the time at normal operating temperatures. But they have the disadvantage of operating mostly under the high pressures and combustion heat of full-load operation.

Engineers who studied the problem noted that engine oils were compounded basically for automotive and truck engines. However, their use left something to be desired when used in off-the-road machines.

To overcome this problem, the engineers worked with oil companies to develop oils that would perform better in farm and industrial engines.

The result was the development of a superior quality of oil which performed very satisfactorily in off-the-road machines.



R 6318

Fig. 47 —— Engine Bearing Corroded By Acid Formations

SUMMARY: SELECTING ENGINE OILS

Follow these general rules to get the best performance from your engine oil:

1. Use reputable brands of oil of the proper viscosity and service ratings as outlined in the operator's manual. If the manufacturer has a special oil which does a better job, use only that oil in your engine. See Figs. 48 and 49 for typical recommendations from one manufacturer.

2. Drain and change oil at recommended intervals. Typical recommendations for off-the-road machines are to change oil for the first time after 20-100 hours. Subsequent changes are made at least every 100-250 hours, with the oil filter being changed at each or at alternate oil changes. For exact intervals, see the machine operator's manual.

NOTE: Always drain out oil while it is hot and before the sludge settles.

3. Select only oils which have been performance-tested . . . those having passed oil industry and machine manufacturer's tests.

4. Never mix oils of various MIL Specifications such as S-1 and S-3 or S-3 and MIL-L-2104C. Oils carrying a similar MIL Specification can be mixed . . . even though obtained from different suppliers.

5. Use common sense when operating the engine . . . bring the engine up to normal operating temperature each time it is used. This will help reduce engine wear.

6. Keep oil containers covered, sealed, and protected to prevent contamination by dirt or water.

OIL VISCOSITY CHART FOR VARIOUS TEMPERATURES

Depending on the highest expected prevailing termperature for the fill period, use oil of viscosity as shown in the following chart:

Air Temperature	Manufacturer's Special Oil	Other Oils	
		Single Viscosity Oil	Multi-Viscosity Oil
Above 32°F. (0°C)	SAE 30	SAE 30	Not recommended.
−10°F. to 32°F.* (−23 to 0°C)	SAE 10W-20	SAE 10W	SAE 10W-30
Below −10°F.** (−23°C)	SAE 5W-20	SAE 5W	SAE 5W-20

** SAE 5W-20 oil may be used to facilitate starting.*
** * Some increase in oil consumption may be expected when SAE 5W-20 or SAE 5W oils are used. Check oil level more frequently.*
NOTE: The "special oil" in the above chart is a specially fortified oil furnished by one prominent engine manufacturer for use in his tractor and industrial engines.

X7670

Fig. 48 — Typical Oil Viscosity Chart

SINGLE VISCOSITY OILS	
DIESEL ENGINES	**GASOLINE ENGINES**
API Service CD/SD MIL-L-2104C* Series 3*	API Service CD/SE, CD/SD, CC/SD or SD MIL-L-46152 MIL-L-2104C*
MULTI-VISCOSITY OILS	
DIESEL AND GASOLINE ENGINES	
API Service CC/SE, CC/SD or SD MIL-L-46152	

** As further assurance of quality, the oil should be identified as suitable for API Service Designation SD.*

X5817

Fig. 49 — Typical Oil Service Type Chart

Fig. 50 — Check The Engine Oil Level Daily

NOTE: For more on engines, see the FOS "Engines" manual.

STORING AND HANDLING ENGINE OILS

Use care in storing and handling oil to keep out dirt and moisture.

Store oil inside whenever possible — in clean, closed cabinets or rooms. It is best to keep oil relatively warm in the winter. Fig. 51 shows how changes in temperature can draw water into oil barrels.

If stored outside, lay oil barrels on their sides. If they cannot be laid on their sides, tilt them slightly as shown in Fig. 51; turn the barrel so that the bung is at the high side, away from any water which collects.

Keep oil bungs drawn tight. Use wooden mallets to make sure.

Rinse oil containers and funnels in fuel after use. Cover them to keep out dirt, or store them upside down.

When adding oil, clean all dirt from around the filler cap before removing it. (Do the same before unscrewing an oil filter or a filter cap.)

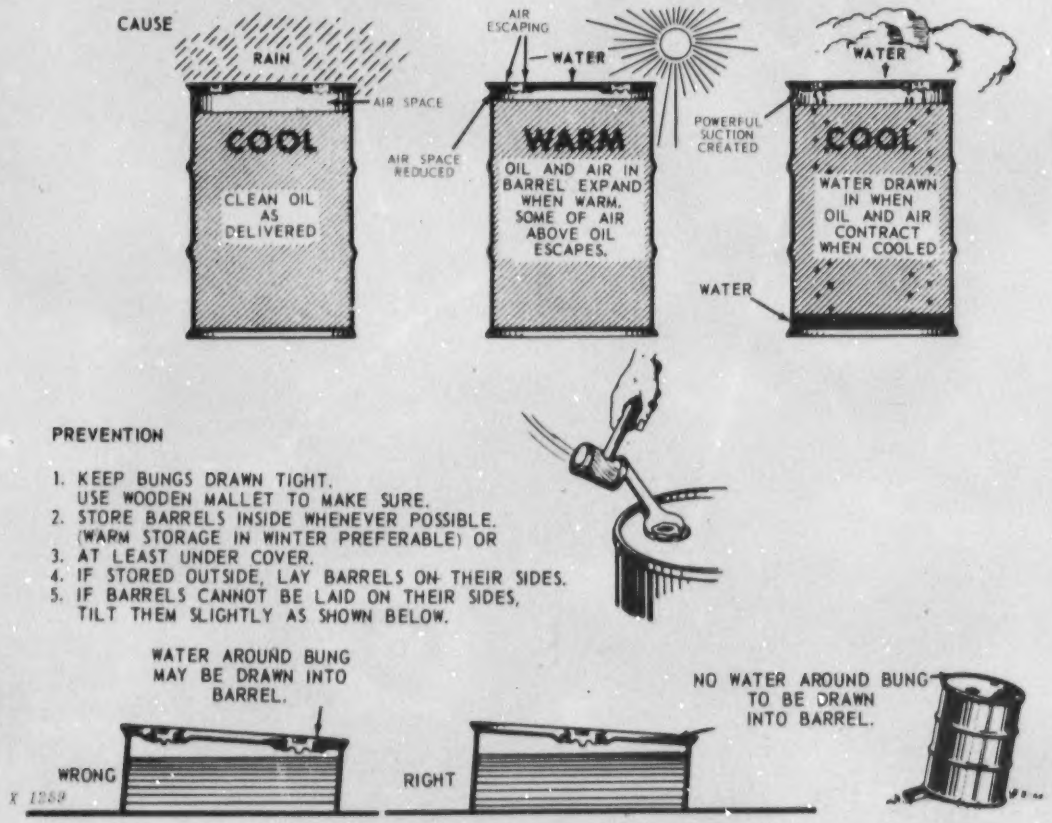

CAUSE
RAIN
AIR SPACE
COOL
CLEAN OIL AS DELIVERED
AIR ESCAPING
WATER
AIR SPACE REDUCED
WARM
OIL AND AIR IN BARREL EXPAND WHEN WARM. SOME OF AIR ABOVE OIL ESCAPES.
WATER
POWERFUL SUCTION CREATED
COOL
WATER DRAWN IN WHEN OIL AND AIR CONTRACT WHEN COOLED
WATER
PREVENTION
1. KEEP BUNGS DRAWN TIGHT. USE WOODEN MALLET TO MAKE SURE.
2. STORE BARRELS INSIDE WHENEVER POSSIBLE. (WARM STORAGE IN WINTER PREFERABLE) OR
3. AT LEAST UNDER COVER.
4. IF STORED OUTSIDE, LAY BARRELS ON THEIR SIDES.
5. IF BARRELS CANNOT BE LAID ON THEIR SIDES, TILT THEM SLIGHTLY AS SHOWN BELOW.
WATER AROUND BUNG MAY BE DRAWN INTO BARREL.
WRONG
RIGHT
NO WATER AROUND BUNG TO BE DRAWN INTO BARREL.

Fig. 51 — Storage Practices Which Prevent Contamination Of Oil

Litho In U.S.A.

GEAR OILS

Gear oils are those used in enclosed gear boxes to lubricate mechanical transmissions, differentials, and steering gears.

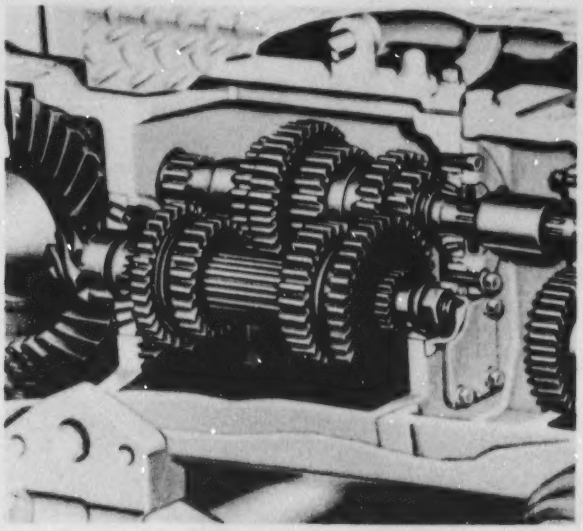


Fig. 52 — Transmission-Differential Unit Which Operates In Oil Bath

Today's high-speed, high-torque power trains use relatively small gears. The result is high tooth loads and harder rubbing between mating gears. This makes lubrication more critical. Unless a good film of fluid is maintained between the mating gear teeth, they will wear and score (Fig. 53).

GEAR LUBRICATION

In small, simple gear units (Fig. 54), where tooth pressures are relatively light, a simple gear oil is often adequate.

Special gear arrangements such as spiral bevel and worm gears can wear very rapidly unless the correct gear oil is used.

For these higher loads, the gear oil must have special "anti-friction" and "anti-weld" agents. Oils containing these additives are known as **extreme pressure** or **hypoid** lubricants.

GEAR OIL REQUIREMENTS

To perform satisfactorily under today's conditions, most gear oils should have the following properties:

1. Extreme Pressure Properties

Extreme pressure properties are required in gear systems where hypoid, heavily loaded spiral-bevel and worm gear combinations are used. Spur gears and moderately loaded gears do not require this property.

2. Oxidation Stability

Gear lubricants must be chemically stable to resist oxidation and sludge formation under sustained heat with violent agitation and air foaming.

3. Corrosion Resistance

Extreme pressure agents are, by nature, chemically active and protect gear teeth by coating them. Discoloration of gears and internal parts frequently occurs, but this does not indicate abnormal corrosion.

4. Foam Resistance

This is mandatory in gear lubricants because of the violent agitation of the oil. Most gear lubricants contain foam suppressors.

5. Viscosity Index

Because of the wide variation in both ambient and gear case temperatures, a higher viscosity is desirable.

Fig. 53 — Normal Gear Wear And Scoring Wear

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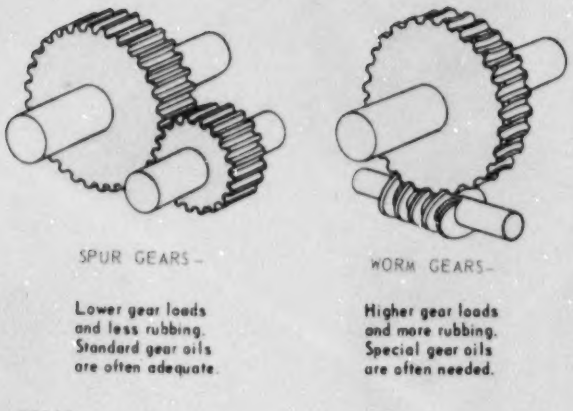
SPUR GEARS-
Lower gear loads and less rubbing. Standard gear oils are often adequate.
WORM GEARS-
Higher gear loads and more rubbing. Special gear oils are often needed.

Fig. 54 — Gear Oils Must Match The Gear Load

6. Pour Point

The pour point must be low enough to provide lubrication at the lowest anticipated temperature. Low viscosity gear oils normally have a low pour point (down to −50°F) (−46°C).

7. Channel Temperature

Gear oils should be fluid enough at the lowest operating temperature to flow and cover moving parts, rather than to form a channel in which the gears can move free of lubricant. Channel temperatures may be as much as 15°F (−9°C) colder than the specified pour point of the lubricant.

SAE GEAR CLASSIFICATION

Society of Automotive Engineers (SAE) gear oil classification is based on viscosity alone and is no indication of quality or service (see chart).

While the SAE numbers of gear oils are higher than the SAE numbers of engine crankcase oils, gear oils are not necessarily that much higher in viscosity. To avoid confusion, higher numbers are assigned to gear oils (Fig. 55). For example, SAE 80 gear oil actually has about the same viscosity as SAE 20 engine oil.

Multi-grade gear oils are presently available from some suppliers in grades of SAE 75/80, SAE 80/90, and SAE 80/90/140.

Some manufacturers recommend engine crankcase oils for use in standard transmission service, while some transmissions may use SAE 50 engine as an alternate for SAE 90 gear oil. As a result of this, some gear oil containers are marked SAE 50-90 indicating that the viscosity requirements of SAE 50 *engine* oil are met.

SAE GEAR OIL CLASSIFICATION

SAE Viscosity Number	Viscosity Range, Saybolt Universal, Seconds			
	AT 0°F (−18°C)		AT 210°F (99°C)	
	Min.	Max.	Min.	Max.
75	—	15,000	—	—
80	15,000 (a)	100,000	—	—
90	—	—	75	120 (b)
140	—	—	120	200
250	—	—	200	—

(a) Minimum viscosity at 0°F. can be waived, provided viscosity at 210°F. is not below 48 seconds, Saybolt Universal.

(b) Maximum viscosity at 210°F. can be waived, provided viscosity at 0°F. (extrapolated) is not greater than 750,000 seconds, Saybolt Universal.

The viscosity of gear lubricants in this classification shall not be less than 40 seconds, Saybolt Universal at 210°F.

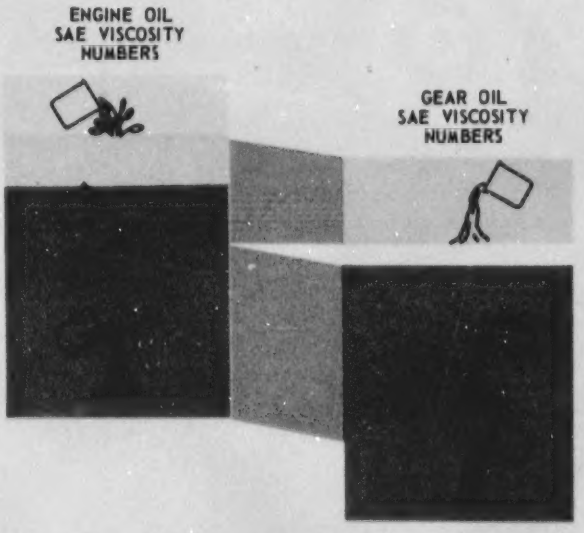

Fig. 55 — To Avoid Confusion, Higher SAE Viscosity Numbers Are Assigned To Gear Oils

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API GEAR OIL SERVICE CLASSIFICATIONS

The API System designates gear lubricants by the types of service for which they may be suitable. *This is not a rating of performance.*

API GL-1

For service in automotive-type spiral bevel, worm gear axles, and some standard transmissions, operating under conditions of low pressures and sliding velocities. Rust and oxidation inhibitors, foam suppressors, and pour point depressants may be used, but friction reducers and extreme pressure agents must not be used.

API GL-2

For automotive-type worm gear axle service, under conditions of load, temperature, and sliding velocities where gear oils for Service GL-1 are not adequate.

API GL-3

For service in manual transmissions and spiral-bevel gear axles, under moderate conditions of speed and load. The service conditions are more severe than those of API GL-1 services, but not as demanding as for GL-4.

API GL-4

For hypoid gears and similar equipment, operating under both high-speed, low-torque and low-speed, high-torque conditions.

API GL-5

This is for service similar to GL-4, but under more severe conditions. It applies to conditions encountered in hypoid gears and other equipment operated under high-speed, high-torque conditions.

API GL-6

For special high-offset hypoid gears operated under high-speed, high performance conditions.

Lubricants indicated for API Service GL-4, GL-5, and GL-6 are applicable for use in non-automatic transmissions and final drives, and are generally available locally.

MILITARY (MIL) OR MANUFACTURER'S SPECIFICATIONS

MIL-L-2105

This has been a long-standing performance level of gear oils determined by test sequences which define MIL-L-2105 Standards. Products meeting this specification are of the API GL-4 type.

While the specification MIL-L-2105 is now obsolete, replaced by the current specification MIL-L-2105B, it is still widely used to indicate a performance level for some gear oils.

MIL-L-2105B

This is the current performance specification of a multi-purpose gear lubricant used under more severe operation than those covered by MIL-L-2105. These gear oils are under API Designation GL-5.

DIFFERENTAL OILS

Conventional Differentials

Differentials in some machines are located in a case with the transmission and use the same oil supply (see Fig. 52). In other machines the differential and final drive are a separate unit and may use any of the oils described above.

Limited Slip Differentials

Limited-slip differentials (Fig. 56), are designed to transmit the major driving force to that wheel which has the most traction.

Frequently, when using machines equipped with these differentials, a loud chatter occurs as the machine turns when multi-purpose gear oils are used. This is caused by "stick-slipping" between the plates because of too much friction.

To overcome this chatter, various anti-friction ingredients must be in the oil. Some manufacturers supply these modifiers as an additive to supplement the regular multi-purpose gear oils. But usually these additives are already in the oil recommended for the unit.

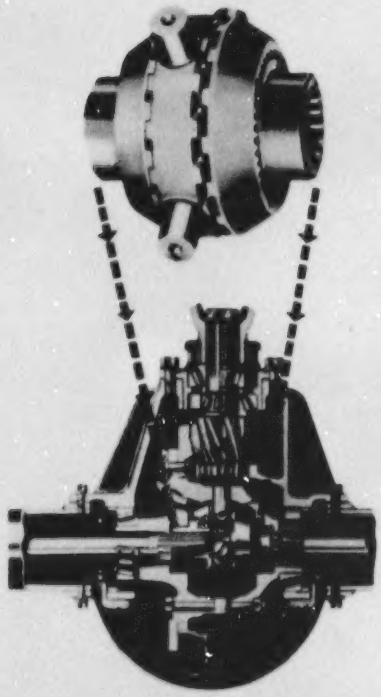

Fig. 56 — Limited Slip (No Spin) Differential

HYDRAULIC AND TRANSMISSION FLUIDS

In this section we will cover fluids for automatic transmissions, torque converters, hydraulic systems, and transmission-hydraulic units.

AUTOMATIC TRANSMISSION FLUIDS

When the first automatic transmissions came out in the late 1930's, it was apparent that regular transmission oils were unable to meet the severe demands required by these units. Joint development work soon produced a specific product known as "automatic transmission fluid."

In the late 1940's, General Motors Research issued the first ATF (Automatic Transmission Fluid), Type A Specifications. These specifications defined the qualities and tests to insure the fluids had the qualities for satisfactory service.

The Armour Research Foundation conducted these tests and the approved fluids were then identified by an "Armour Qualification Number," such as AQATF, where the qualification number followed the ATF.

Specifications were changed in the late 1950's to include a more severe method of determining the oxidation resistance of the ATF. The new fluid, which passed this test, was then known as *Automatic Transmission Fluid,* **Type A**, *Suffix A* and a new qualification of existing products was required.

ATF specifications were updated again in the late 1960's when Ford Motor came out with a new fluid specification, **Type F**.

Meanwhile, General Motors issued specifications for a new fluid, called **DEXRON**, which has been adopted by all divisions of General Motors and is recommended for many other applications as well. As a result, most vehicle manufacturers now recommend DEXRON, while some still say "DEXRON or Type A, Suffix A." The exception is Ford Motor, which recommends Type F.

These qualification numbers now appear on each container of automatic transmission fluid.

FUNCTIONS

The prime jobs of an automatic transmission fluid are:

- **Act as a medium to transmit power.**
- **Act as a lubricant for gears, clutch plates, and bearings.**
- **Act as a medium to transfer heat.**

Inside an automatic transmission, the lubricant must perform specific functions under severe conditions. These are:

1. Protect heavily-loaded helical and spiral gears with an oil film cushion.

2. Perform as a non-foaming fluid in transmitting power.

3. Operate as a hydraulic fluid between −30° and 300°F (−34° and 149°C).

4. Act as a wet clutch and transmission lubricant to provide smooth, silent engagement, without slipping.

5. Resist oxidation under conditions of heat and aeration, while at the same time be compatible to all metals, rubber seals, gaskets, adhesives, facings, and liners in the system.

ADDITIVES FOR AUTOMATIC TRANSMISSION FLUIDS

As with engine oils, a variety of additives are needed for automatic transmission fluids.

The chart on the next page shows the most common additives, and gives their compositions, reasons for use, and probable action in the fluid.

ADDITIVES FOR AUTOMATIC TRANSMISSION FLUIDS (COMMONLY USED)

Additive	Type Compounds Commonly Used	Reason For Use	Probable Action
Oxidation Inhibitors	Zinc dithiophosphates, hindered phenols, aromatic amines, sulfurized phenols.	Retard oxidative decomposition of the oil which can result in varnish, sludge and corrosion.	Decompose peroxides, inhibit free radical formation and passivate metal surfaces.
Dispersants	High molecular weight alkyl succinimides, alkylthiophosphonates, organic boron compounds.	Maintain cleanliness by keeping oil insoluble material in suspension.	Primarily a physical process. Dispersant is attracted to sludge particle by polar forces. Oil solubility of dispersant keeps sludge suspended.
Metal Deactivators	Zinc dithiophosphates, organic sulfides, certain organic nitrogen compounds.	Passivate catalytic metal surfaces to inhibit oxidation.	Form inactive protective film on metal surface. Form catalytically inactive complex with metal ions.
Viscosity Index Improvers	Methacrylate polymers, butylene polymers, polymerized olefins or isoolefins, alkylated styrene polymers, various selected copolymers.	Lower the rate of change of viscosity with temperature.	V.I. improvers are less affected by temperature than oil. They raise the viscosity at 210°F. more in proportion than at 100°F. due to changes in solubility.
Anti-Wear Agents	Zinc dithiophosphates, organic phosphates, and acid phosphates, organic sulfur and chlorine compounds, sulfurized fats, certain amines.	Reduce friction, prevent scoring and seizure. Reduce wear.	Film formed by chemical reaction on metal contacting surfaces which has lower shear strength than base metal, thereby reducing friction and preventing welding and seizure of contacting surfaces when oil film is ruptured.
Rust Inhibitors	Metal sulfonates, fatty acids and amines.	Prevent rusting of ferrous parts during storage and from acidic moisture accumulated during cold operation. This is a specific type of corrosion.	Preferential adsorption of polar type surface active material on metal surfaces. This film repels attack of water. Neutralizing corrosive acids.
Corrosion Inhibitors	Zinc dithiophosphates, metal phenolates, basic metal sulfonates.	Prevent attack of corrosive oil contaminants on bearings and other parts.	Neutralization of acidic material and by the formation of a chemical film on metal surfaces.
Foam Inhibitors	Silicone polymers.	Prevent the formation of stable foam.	Reduce surface tension which allows air bubbles to separate from the oil more readily.
Seal Swellers	Organic phosphates, aromatics, halogenated hydrocarbons.	Swell seals slightly, reducing leakage.	Mild chemical modification of seal elastomer.
Friction Modifiers	Organic fatty acids and amides, lard oil, sperm oil, high molecular weight organic phosphorus acids and esters.	Reduce the static coefficient of friction.	Preferential adsorption of surface active materials.

AUTOMATIC TRANSMISSION OIL SERVICE

Some manufacturers do not recommend draining and replacing fluid during the life of the machine. However, automatic transmissions are susceptible to failure under both overheated and overloaded conditions. These include "stop and go" driving and towing heavy loads as well as overload conditions. Therefore, check the fluid level at the recommended intervals and watch for trouble signs in the fluid.

TORQUE CONVERTER OIL SERVICE

Automatic transmission fluids, Type A and Suffix A, have proven satisfactory for torque converters in heavy-duty trucks, buses, and industrial machines.

More recently, this specification has been replaced by DEXRON from General Motors, and Type F from Ford Motor.

However, torque converters may require different qualities from an automatic transmission fluid.

In the mid 1950's the Allison Division of General Motors provided a specification "Hydraulic Transmission Fluid, Type C," later amended to "Hydraulic Fluid, Type C-1 and then to **Type C-2.**" This covers many heavy-duty oils in the SAE 10W and SAE 20W viscosities as well as the automatic transmission fluids. It has since been found that oils in the SAE 10W viscosity were most desirable.

Although General Motors was originally responsible for the C-1 and C-2 designations; many other manufacturers of heavy-duty torque converters recommend fluids of this type.

HYDROSTATIC DRIVE OIL SERVICE

Like torque converters, hydrostatic drives can use automatic transmission fluids, but may require different qualities in the fluid. For example, an off-the-road machine operated in the arctic will need a fluid with a very low pour point. Always follow the recommendations in the machine operator's manual.

TRANSMISSION-HYDRAULIC FLUIDS

In recent years, a number of farm and industrial manufacturers have designed machines with a common reservoir for the transmission and hydraulic systems (Fig. 57). This means that the same lubricating fluid may have to serve the gear train, differential, hydraulic clutches, disk brakes, as well as the hydraulic system and the power steering.

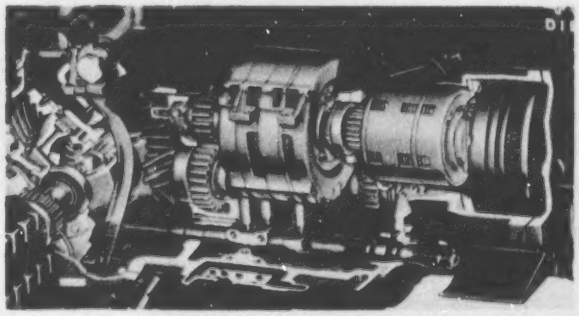

Fig. 57 — Transmission-Hydraulic Oil Reservoir in Modern Tractor

Here are some of the fluids that have been developed for these services:

- **John Deere 303 Special Purpose Fluid**
- **International Harvester Hy-Tran B-6 Fluid**
- **Allis Chalmers A-26 Fluid**
- **Case TCH Fluid**
- **Ford M2C41-A Fluid**

These fluids are referred to as *four-way oils* because of the wide range of services they must perform. Here are their key properties:

1. High oxidation stability for long life and protection.

2. Low pour point for low temperature service, particularly during cold starting.

3. High viscosity index for best viscosity under various operating temperatures.

4. Contain extreme pressure additives for increased load carrying and wear protection under heavy and shock loads.

5. Contain rust and corrosion inhibitors.

6. Compatible with all types of seals.

7. Contain foam suppressors.

Some fluids which serve as transmission-hydraulic fluids also operate wet brake systems and require additives to control chatter.

While no transmission-hydraulic fluid will fully meet each specific need for every machine, products are available which will meet the service demands in any one machine for which these oils are specified.

Always use the oil specified by the manufacturer. Through exhaustive tests, he has determined which oil will give the best service in his machine and his own special designs.

HYDRAULIC FLUIDS

FUNCTIONS

The prime job of a hydraulic fluid is to transmit power. However, the fluid must also be stable over long periods and must protect the machine against rust and corrosion. The fluid must also act as a lubricant and a heat absorber for the working parts. Furthermore, it must be readily available and economical.

PROPERTIES

Hydraulic fluid should have these properties:

1. Viscosity

Viscosity is probably the single most important property of a hydraulic fluid. The parts of a hydraulic system depend on close fits to create and maintain the necessary pressures.

Too-low viscosity oils can cause leakage, while too-high viscosity can cause sluggish operation, heating, and high pressures.

2. Stability

Hydraulic fluids are subject to heat, agitation and aeration, which are ideal conditions for oxidation and deterioration. In well-kept systems, where there is little fluid loss, and the oils will be in service for

long periods, oxidation inhibitors are very necessary. The rate of oil oxidation doubles for each 20°F. rise in temperature. Because of this, some manufacturers provide coolers to control the oil temperatures and reduce oxidation.

3. Corrosion Resistance

Two types of corrosion are found in hydraulic systems: *rusting* and *acid*.

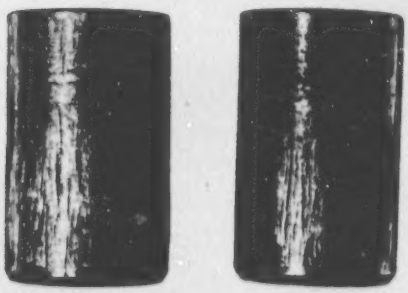

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Fig. 58 — Contaminated Hydraulic Fluid Scored These Hydraulic Pump Pistons

Since hydraulic systems are vented, it is impossible to prevent reservoir "breathing" and the intake of moisture and condensation. This can cause **rusting** of metal parts.

Since only a very small degree of rusting and pitting can adversely affect the operation of the finely machined parts in the system, be sure that the oil contains a very potent rust inhibitor. They control rusting by displacing the water from the metal surfaces, and then adhering to these same parts to prevent water-to-metal contact.

Acid corrosion is a result of oxidation of oil products. This can be controlled by oil coolers to eliminate conditions for oil oxidation, and by the use of the oxidation inhibitors we have already discussed.

4. Pour Point

Pour point is of prime importance to mobile and outdoor equipment. In some northern areas, winter temperatures fall far below the natural pour point of most oils. Therefore, the oil must be fortified with pour point depressants to allow it to flow at sub-zero temperatures.

5. Anti-Foam

Foaming in hydraulic fluids can be caused by excessive agitation in the presence of air, by air leaking into the system, or by contaminants such as dirt and water. Chronic foaming is a design problem and should be treated as such. For added protection, most hydraulic fluids contain a small amount of silicone material. This does not prevent foaming but causes the foam to be very unstable and to break down rapidly.

6. Anti-Wear

Vane-type hydraulic pumps are very susceptible to wear. Service instructions from these pump manufacturers recommend only oils that contain antiwear compounds.

7. Compatible With Seals

Seals in the hydraulic system contain rubber and other materials which could deteriorate if oil contains harmful materials. For this reason, the oil must be made compatible with seals in the system.

SELECTION OF HYDRAULIC FLUIDS

The oil in a hydraulic system serves as the power transmission medium. It is also the system's lubricant and coolant. Selection of the proper oil is a requirement for satisfactory system performance and life. Oil must be selected with care and from a reputable supplier.

Depending upon the system, these types of oils *may* be suitable:

1. **Crankcase Oil** meeting API service classification MS or SD. The most severe classification is the key to proper selection of crankcase oils for mobile hydraulic systems.

2. **Antiwear-Type Hydraulic Oil** — There is no common designation for oils of this type. However, they are produced by all major oil suppliers and provide the antiwear qualities of MS or SD crankcase oils.

3. **Certain Other Types Of Petroleum Oils** are suitable for mobile hydraulic service if they meet the following provisions:

   (a) Contain the type and content of antiwear compounding found in MS or SD crankcase oils or have passed pump tests similar to those used in developing the antiwear-type hydraulic oils.

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(b) Meet the viscosity recommendations for expected temperatures.

(c) Have sufficient chemical stability for mobile hydraulic system service.

The following types of oil are suitable if they meet the above three provisions:

Automatic Transmission Fluid Type A, Suffix A, Type F and DEXRON
Hydraulic Transmission Fluid Types C-1 and C-2

When selecting hydraulic fluids, check the recommendations in your operator's manuals. The manufacturer has picked a fluid which meets all the needs of his system, which may vary from simple cylinders to precision hydraulic pumps.

HYDRAULIC OIL FILTERS

Hydraulic systems normally use an oil filter similar to those used to filter the engine crankcase oil. Always use the replacement filter recommended by the manufacturer.

NOTE: For more on hydraulic systems, see the FOS "Hydraulics" manual.

STORAGE AND HANDLING

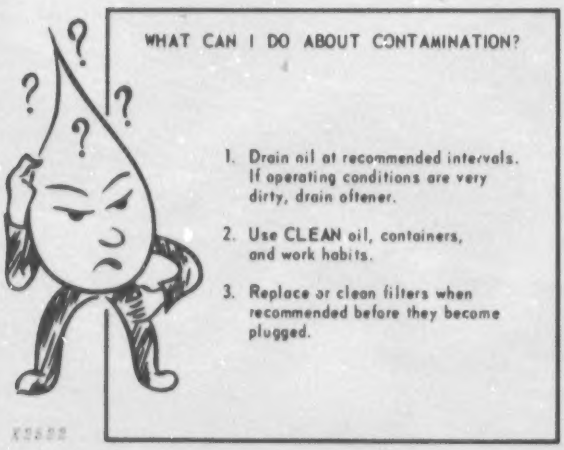
WHAT CAN I DO ABOUT CONTAMINATION?
1. Drain oil at recommended intervals. If operating conditions are very dirty, drain oftener.
2. Use CLEAN oil, containers, and work habits.
3. Replace or clean filters when recommended before they become plugged.

Fig. 59 — What Can I Do About Contamination?

Use the same care and precautions in storage and handling of transmission and hydraulic oils as recommended for engine oils. Be sure to prevent the entrance of dirt or moisture into the oil. Just a little dirt, mixed with oil, makes an excellent grinding compound!

LUBRICATING GREASES

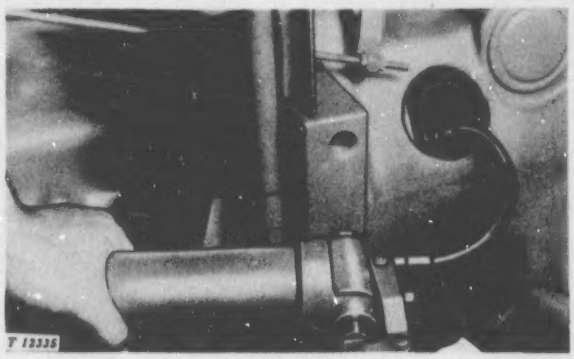

Fig. 60 — Applying Grease To Pressure Fitting Using Hand Gun

Lubricating grease is normally a blend of lubricating oil and soap with stabilizers and additives. The kind of soap used determines the special properties of the grease. Calcium, sodium, and lithium soaps are most commonly used:

- **Calcium soap — pressure gun or chassis grease**
- **Sodium soap — wheel bearing grease**
- **Lithium soap — multi-purpose grease**

GREASE ADDITIVES

Some special greases contain non-soap thickeners. Fillers are also sometimes added to greases to add bulk and to harden the grease.
Many additives in grease are similar to those in oils: oxidation and corrosion inhibitors, anti-scuff agents. Other additives special to grease are chemical stabilizers and those which increase the dropping point (when grease liquifies).

HIGH-TEMPERATURE GREASES

High-temperature greases are formulated so that they resist heat and do not liquefy. Special thickeners are used in place of the conventional soaps to get this quality.

EXTREME-PRESSURE GREASES

Extreme-pressure (E.P.) greases have the ability to maintain a film on metal surfaces to prevent wear under high sliding loads or slow motions in the mechanism. Additives used to get this quality are most often molybdenum disulfide or lead naphthenate.

MULTI-PURPOSE GREASES

The development of *multi-purpose grease* has made it possible for the machine operator to use one grease for almost all fittings and hand-packed bearings.

Many operator's manuals recommend wheel bearing grease for packing wheel bearings, but multi-purpose grease is now considered to be satisfactory for some wheel bearing lubrication. It is recommended that wheel bearings be packed only one-half full with multi-purpose grease.

Multi-purpose grease is water-resistant, will withstand high temperature, protects against rust, and is long lasting. It may also have some of the qualities of extreme-pressure or high-temperature greases.

GENERAL SUGGESTIONS

1. Keep the grease containers in a dust-free place.
2. Wipe off the grease gun before filling it.
3. Fill the grease gun without exposing the grease to dust and dirt.
4. Always wipe off grease fittings before applying grease. Don't force dirt into a bearing. Wipe off excess grease after greasing.
5. Grease the machine at the end of the day when it is warm.

TEST YOURSELF

QUESTIONS

1. Which oil is thicker, SAE 10 or SAE 30?
2. Which API-classified oil is for more severe or high-output service — CA or CD?
3. Name any three additives used in engine oils.
4. True or false? "Oil doesn't wear out."
5. What is the prime cause of engine crankcase oil which thins out?
6. True or false? "The additive content of all SD oils are not alike."
7. True or false? "Black oil means time for an oil change."
8. Does SAE 80 gear oil have about the same viscosity as SAE 20 engine oil?
9. Which of the qualities below must a hydraulic fluid have?
   a. Transmit power
   b. Protect against corrosion
   c. Absorb heat
   d. Lubricate working parts

(Answer on page 68.)

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COOLANTS / PART 3

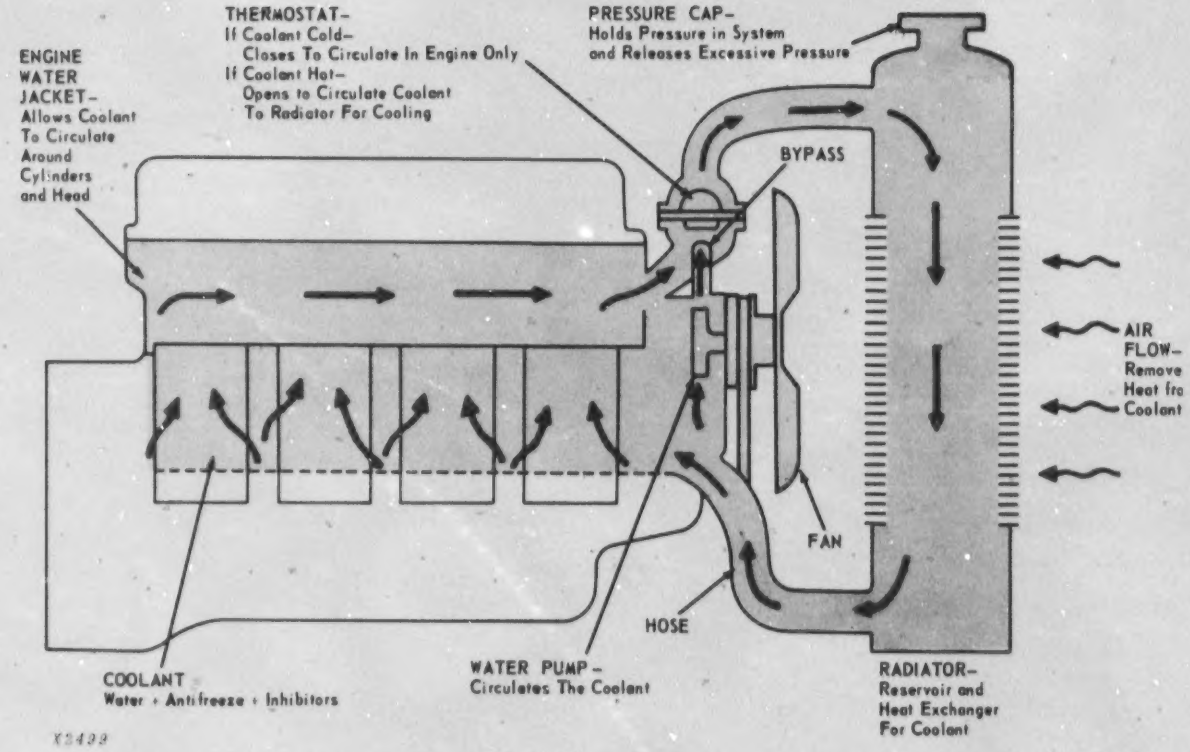


Fig. 61 — Liquid Cooling System

INTRODUCTION

When an engine burns fuel, heat is created — peaks of 4000°F (2200°C) are not uncommon. Since the best engines can only use about 35 percent of this heat for power, the excess heat must be removed. If not, pistons would be scored, valves burned, and bearings seized.

To help dissipate heat, two types of cooling systems are used on modern engines:

- **Air Cooling — uses air passing around the engine to dissipate heat.**
- **Liquid Cooling — uses a liquid to cool the engine and air to cool the liquid.**

AIR COOLING is used only on small engines as it is difficult to route air to all the heat points of larger engines. Metal baffles, ducts, and blowers are used to aid in distributing air. There is no cooling liquid.

LIQUID COOLING (Fig. 61) normally uses water as a coolant. In cold weather, antifreeze solutions are added to the water to prevent freezing. The water circulates in jackets around the cylinders and other friction parts. As heat radiates, it is absorbed into the water, which then flows to the radiator. Air flow through the radiator cools the water and dissipates heat into the air. The water then recirculates into the engine to pick up more heat.

In this section we will cover only the **liquid** cooling systems used on most large modern engines.

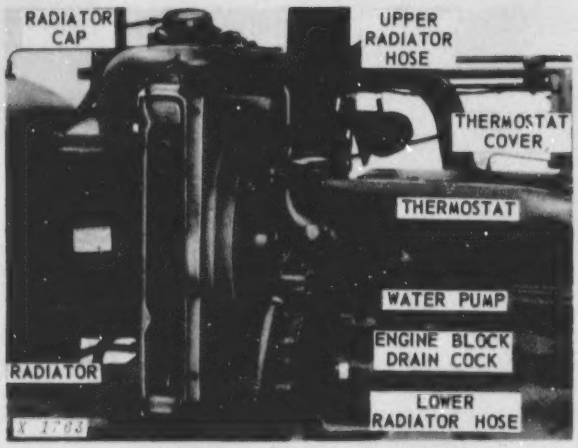


Fig. 62 — Engine Cooling System

PARTS OF LIQUID COOLING SYSTEMS

A liquid system (Fig. 62) consists of the following:

- **Radiator and Pressure Cap**
- **Fan and Fan Belt**
- **Water Pump**
- **Engine Water Jacket**
- **Thermostat**
- **Connecting Hoses**
- **Liquid or Coolant**

The RADIATOR is one of the major components of any liquid cooling system. It is here that heat in the coolant is released to the atmosphere. It also provides a reservoir for enough liquid to operate the cooling system efficiently.

The FAN forces cooling air through the radiator core to more quickly dissipate the heat being carried by the coolant in the radiator.

The WATER PUMP circulates the coolant through the system. The pump draws hot coolant from the engine block and forces it through the radiator for cooling.

Some engines have distribution tubes and some have transfer holes which direct extra coolant flow to "hot" areas, such as exhaust valve seats.

CONNECTING HOSES are the flexible connections between the engine and other parts of the cooling system.

The THERMOSTAT is a heat-operated valve. It controls the flow of coolant to the *radiator* to maintain the correct operating temperatures. When the coolant is cold, the thermostat closes to bypass coolant around the engine for faster warm-ups. When the coolant gets warm, the thermostat opens to circulate coolant through the radiator for normal cooling. The FAN BELT transmits power from the engine crankshaft to drive the fan and water pump.

COOLANT is the liquid that circulates through the cooling system carrying heat from the *engine water jacket* into the *radiator* for transfer to the outside air. The coolant then flows back through the engine to absorb more heat.

In the remainder of this section, our main interest will be **coolants** — the medium which carries away excess heat from the engine.

NOTE: For more details on the parts of the liquid cooling system, see the FOS manual on "Engines."

DEVELOPMENT OF LIQUID COOLING

Early engines had open water hoppers around the cylinders which kept them cool. However, the water could boil away.

Later engines had a closed *water jacket* and *radiator*, and the water circulated naturally. As water heated and became lighter, it rose and was replaced by cooler water. Still later, a *water pump* was added to circulate the water.

However, these systems did not really control the engine temperature. When the air was cool, the engine ran cool; but when the air was hot, the engine ran hot.

To make engines more efficient, a *thermostat* was added to keep the engine at a constant temperature. By varying how much coolant flows to the radiator for cooling, the thermostat can regulate the temperature of the engine.

But as large modern engines were developed, even more heat control was needed. This led to the *pressure cap* which relieves pressure from too much heat and also lets in air pressure when the liquid cools. With a pressure cap, the boiling point of the coolant can be raised (a 7 psi (43 kPa) cap raises it from 212°F to about 230°F (100° to 110°C). The cap not only prevents loss of coolant through overflow on rough terrain, it also prevents loss due to boiling in hot conditions.

WATER AS A COOLANT

Water is the universal coolant for engines.

It has many **advantages**:

1. *Plentiful and cheap*
2. *Absorbs heat well*
3. *Circulates freely*
4. *Harmless to handle*

The **disadvantages** of water are:

1. *Will freeze at 32° F (0° C)*
2. *Can corrode metal parts*
3. *Can leave deposits*
4. *Will evaporate*

In effect, **water by itself is not a satisfactory coolant.** Without inhibitors it will rust, corrode, and leave deposits in the engine (Fig. 63). Without an antifreeze solution, it will freeze at 32° F (0° C).

The best water for coolant is clean soft water — rain water is the best source. Ground water is too hard and contains minerals which form scale in the engine. Artificially softened water is better, but there is still dissolved materials in it. Even distilled water, while the purest of all, still needs inhibitors.

The problem is that **all** waters tend to either corrode or form deposits. Waters that have been softened may tend to corrode metal parts, while harder tap waters tend to form deposits.

The safest rule is to add **inhibitors** to the water even in summer to prevent rust, corrosion, and deposits.

Most antifreeze solutions have these inhibitors, while for summer operation, various inhibitor compounds or conditioners are available.

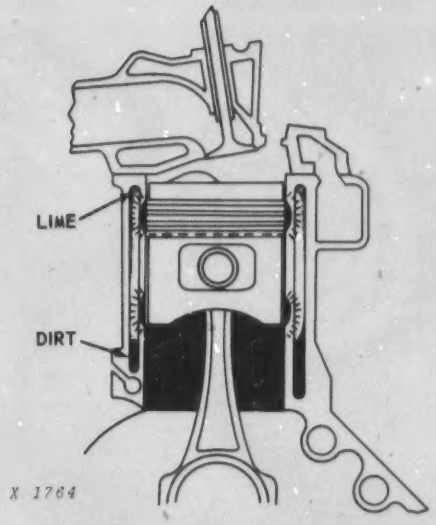


Fig. 63 — Using Hard Water As A Coolant Can Leave Mineral Deposits In The Engine

ANTIFREEZES

Where freezing is expected, the cooling system must have a coolant which will not readily freeze.

If the coolant freezes, it will expand and may crack the engine block or head and create leaks. It may also weaken the radiator and hoses. During operation, freezing can prevent circulation and cause the engine to run hot.

WHAT ANTIFREEZES MUST DO

Several materials, alone or mixed with water, will prevent freezing. However, only a few meet all the requirements below.

Antifreeze solutions must:

1. *Prevent freezing at lowest expected temperatures*
2. *Inhibit rust and corrosion of system parts*
3. *Be chemically stable*
4. *Not conduct electricity (which can corrode)*
5. *Flow readily at all temperatures*
6. *Conduct heat readily*
7. *Resist foaming*

Other minor requirements are that the antifreeze should not lower the boiling point of water too much, not expand too much, and not have too unpleasant an odor.

The materials which come closest to satisfying these requirements are compounds of the simple alcohols (methyl, ethyl, and isopropyl) and of ethylene glycol. These are used in most of today's antifreeze solutions, which we'll look at now.

TYPES OF ANTIFREEZES

Most modern engines use one of two types of antifreeze:

- **Alcohol base**
- **Ethylene glycol base**

Since most modern engines operate at temperatures above the boiling point of alcohol (Fig. 64), the permanent-type — ethylene glycol — is usually recommended.

The term "permanent antifreeze" means only that the solution will not boil away at normal engine temperatures. It does **not** mean that the good qualities of the solution never wear out.

Let's look at the two major types of antifreezes in detail.

ALCOHOL ANTIFREEZE

The boiling point of alcohol solutions is just below that of water (Fig. 64) and the difference increases with the concentration of alcohol.

The boiling point of liquids decreases about 2°F (−17°C) for each 1000 feet (305 meters) of altitude above sea level. For this reason, alcohol may boil away if used in high regions.

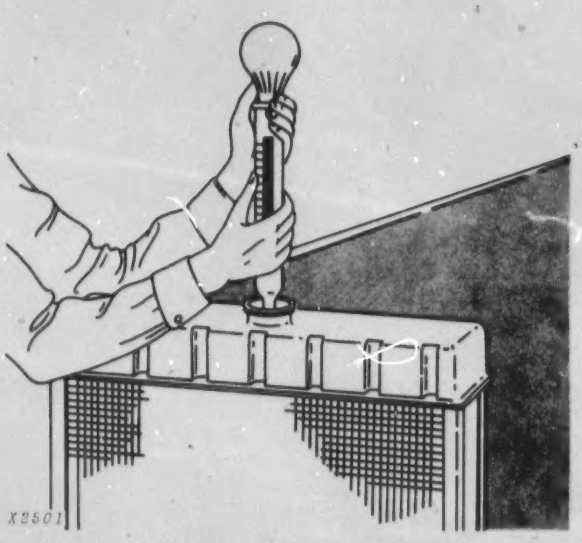


Fig. 65 — Checking Freezing Protection Using A Hydrometer

While alcohol antifreeze is satisfactory for some systems, it tends to boil and to create hazards at the pressure cap in many modern systems. So it is not widely recommended today.

ETHYLENE GLYCOL ANTIFREEZE

Ethylene glycol, or "permanent" antifreeze is widely used in modern pressurized systems because of its boiling point, which is higher than that of water (Fig. 64).

However, glycol antifreeze solutions can still boil and be lost through the overflow pipe, even though at a higher temperature. But any evaporation loss from a glycol solution is practically all water, which keeps the freezing protection in the system.

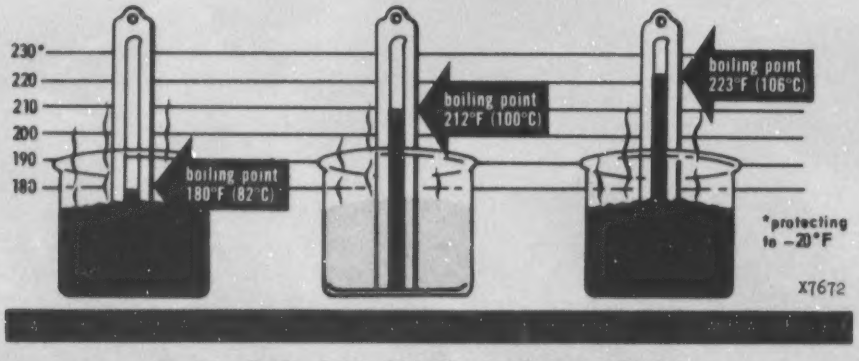


Fig. 64 — Boiling Points Of Antifreezes Compared To Water

A good solution of glycol with inhibitors can protect the system for a full season, and some manufacturers extend this to two seasons. Another maker produces a solution which changes color as it fails, telling that it is time to replace.

Glycol solutions, like alcohol solutions, can be weakened by hard or long service or by lack of good maintenance. Inhibitors can deplete from severe operation, high engine speeds, heavy loads or air leaks into the cooling system. Exhaust gas passing into the water jacket through a leaking head gasket (Fig. 66) can weaken the solution. Other causes are hot spots in the engine and contaminants such as radiator cleaners that are not flushed out after use.

Glycol Ether Antifreeze

Glycol ether antifreeze should not be confused with the better-known ethylene glycol. Glycol ether is higher in price and has an odor similar to that of ether. It has the advantage of mixing with oil if it should leak into the engine crankcase.

However, tests have shown that use of glycol ether causes some swelling of engine hoses and also a cleaning effect on rust and scale deposits inside the cooling system. This can cause problems of clogging unless the system is properly drained, flushed, and chemically cleaned *before* the antifreeze is installed.

WHICH ANTIFREEZE TO USE?

The types of antifreeze to use is determined by:

1. *Expected service*
2. *Local climate*

The operator's manual is the guide for this. Use low-boiling point alcohol antifreezes only if recommended, and be sure that the pressure cap is in good condition so that efficient temperatures can be maintained. Always use the pressure cap recommended for the system.

However, most modern systems work better with high-boiling point antifreezes of the "permanent" glycol types. High-combustion, high-speed engines need more heat to operate efficiently.

FREEZING PROTECTION FOR COOLANT

When you add antifreeze, protect for the **lowest** expected temperatures. The map in Fig. 67 on the next page shows the lowest temperature observed in various parts of the United States during the past 50 years (from U.S. Weather Bureau records).

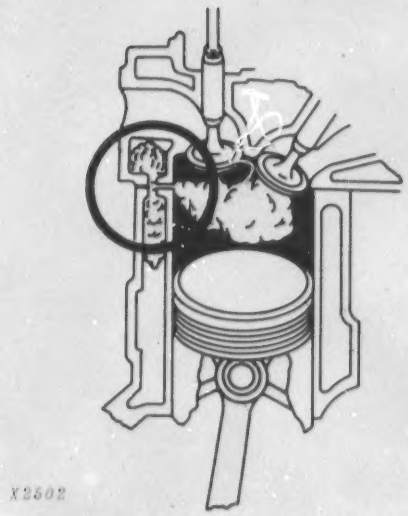


Fig. 66 — Exhaust Gas Leaking Into The Cooling System Can Weaken Coolant And Also Cause Foaming, Overheating, And Overflow

Check your operator's manual for the system capacity of your machine. Then use the chart in Fig. 67 to find how much full-strength "permanent" antifreeze is required to protect to the lowest expected temperature.

Install and maintain a 33 to 50 percent concentration — 0°F (−18°C) freezing protection — for adequate corrosion protection. A 50 percent solution will provide protection to −34°F (−32°C). A 68 percent solution will protect to about −90°F (−68°C).

Because of the nature of ethylene glycol, a greater concentration of antifreeze will actually give **less** protection. Examples of this are that an 80 percent solution will provide protection to −57°F (−49°C) and a 100 percent solution provides protection only to −9°F (−23°C).

TESTING ANTIFREEZE SOLUTIONS

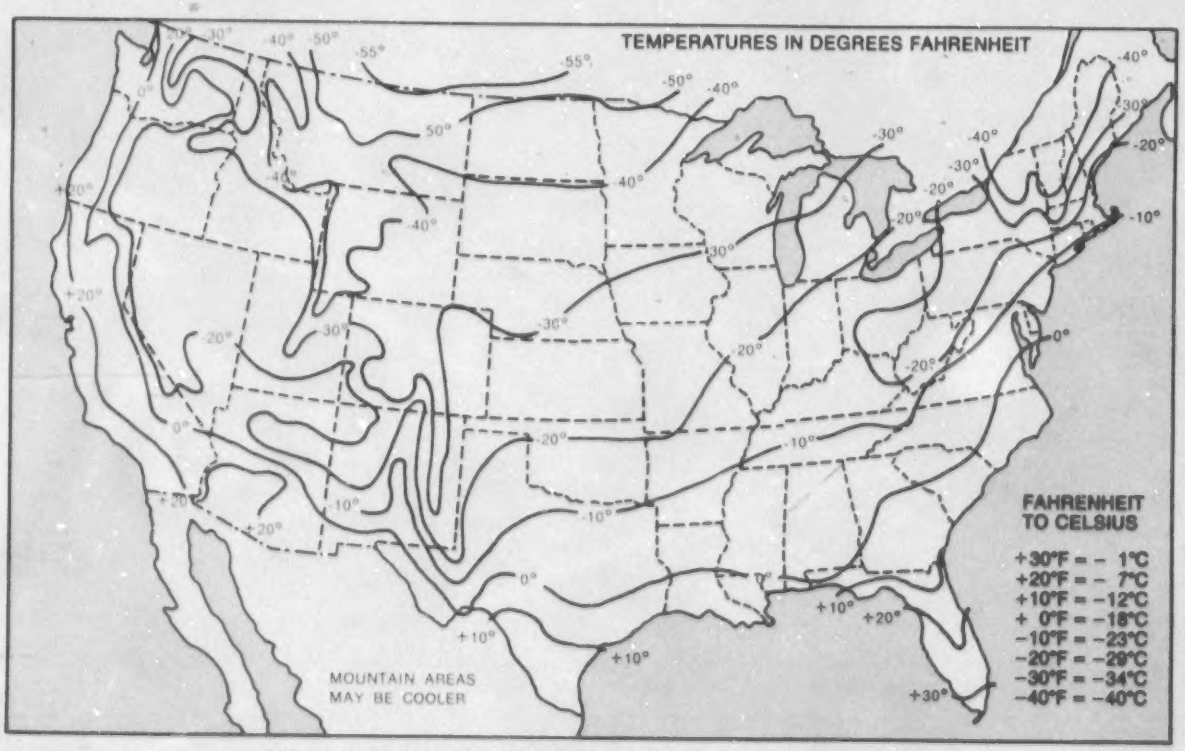
A **hydrometer** (Fig. 65) is commonly used to test the freezing protection of antifreeze solutions. It should have a thermometer and a correction table.

If a simple hydrometer is used, it will give a correct reading only at one temperature — usually 60°F (16°C). This is because the density of a liquid changes with the temperature. Also, if two types of antifreezes are mixed, the hydrometer reading will not be accurate. Therefore, be sure the hydrometer has a thermometer built in.

FREEZING PROTECTION TABLE

Cooling System Capacity Quarts (Liters)	FULL STRENGTH "PERMANENT" ANTIFREEZE REQUIRED												
	Quarts												
	1 °F (°C)	2 °F (°C)	3 °F (°C)	4 °F (°C)	5 °F (°C)	6 °F (°C)	7 °F (°C)	8 °F (°C)	9 °F (°C)	10 °F (°C)	11 °F (°C)	12 °F (°C)	13 °F (°C)
5 (4.7)	16° (- 9.0°)	12° (-22.0°)	-62° (-52.0°)										
6 (_5.7)	19° (- 7.0°)	0° (-17.5°)	-34° (-36.5°)										
7 (6.6)	22° (- 5.5°)	7° (-14.0°)	-17° (-27.0°)	-54° (-47.5°)									
8 (7.6)	23° (- 5.0°)	11° (-12.0°)	- 7° (-14.0°)	-34° (-36.5°)	-69° (-56.0°)								
9 (8.5)	24° (- 4.5°)	14° (-10.0°)	0° (-17.5°)	-21° (-29.5°)	-50° (-45.5°)								
10 (9.5)	26° (- 4.0°)	16° (- 9.0°)	4° (-15.5°)	-12° (-24.5°)	-34° (-36.5°)	-62° (-52.0°)							
11 (10.4)	26° (- 3.5°)	18° (- 8.0°)	8° (-13.5°)	- 6° (-21.0°)	-23° (-31.0°)	-47° (-44.0°)							
12 (11.4)		19° (- 7.0°)	10° (-12.0°)	0° (-17.5°)	-15° (-26.0°)	-34° (-36.5°)	-57° (-49.5°)						
13 (12.3)		21° (- 6.0°)	13° (-10.5°)	3° (-16.0°)	- 9° (-23.0°)	-25° (-31.5°)	-45° (-43.0°)	-66° (-55.5°)					
14 (13.2)			15° (- 9.5°)	6° (-14.5°)	- 5° (-20.5°)	-18° (-28.0°)	-34° (-36.5°)	-54° (-47.5°)					
15 (14.2)			16° (- 9.0°)	8° (-13.5°)	0° (-17.5°)	-12° (-24.5°)	-26° (-32.0°)	-43° (-41.5°)	-62° (-52.0°)				
16 (15.1)			17° (- 8.5°)	10° (-12.0°)	2° (-16.5°)	- 8° (-22.0°)	-19° (-28.5°)	-34° (-36.5°)	-52° (-46.5°)				
17 (16.1)			18° (- 8.0°)	12° (-11.0°)	5° (-15.0°)	- 4° (-20.0°)	-14° (-25.5°)	-27° (-33.0°)	-42° (-41.0°)	-58° (-50.0°)			
18 (17.0)			19° (- 7.0°)	14° (-14.0°)	7° (-14.0°)	0° (-17.5°)	-10° (-23.5°)	-21° (-29.5°)	-34° (-36.5°)	-50° (-45.5°)	-66° (-54.0°)		
19 (18.0)			20° (- 6.5°)	15° (- 9.5°)	9° (-13.0°)	2° (-16.5°)	- 7° (-22.0°)	-16° (-26.5°)	-26° (-33.5°)	-42° (-41.0°)	-58° (-49.0°)		
20 (18.9)				16° (- 9.0°)	10° (-12.0°)	4° (-15.5°)	- 3° (-19.5°)	-12° (-24.5°)	-22° (-30.0°)	-34° (-36.5°)	-48° (-44.5°)	-62° (-52.0°)	
21 (19.9)				17° (- 8.5°)	12° (-11.0°)	6° (-14.5°)	0° (-17.0°)	- 9° (-23.0°)	-17° (-27.0°)	-28° (-33.5°)	-41° (-40.5°)	-54° (-47.5°)	-68° (-55.5°)
22 (20.8)				18° (8.0°)	13° (-10.5°)	8° (-13.5°)	2° (-16.5°)	- 6° (-21.0°)	-14° (-25.5°)	-23° (-31.0°)	-34° (-36.5°)	-47° (-44.0°)	-59° (-50.5°)
23 (21.8)				19° (- 7.0°)	14° (-10.0°)	9° (-13.0°)	4° (-15.5°)	- 3° (-19.5°)	-10° (-23.5°)	-19° (-28.5°)	-29° (-34.0°)	-40° (-40.0°)	-52° (-46.5°)
24 (22.7)					15° (- 9.5°)	10° (-12.0°)	5° (-15.0°)	0° (-17.0°)	- 6° (-22.0°)	-15° (-26.0°)	-24° (-31.0°)	-34° (-36.5°)	-46° (-43.5°)

(NOTE: Celsius temperatures above are rounded to nearest 0.5°)



LOWEST TEMPERATURE OBSERVED IN DIFFERENT PARTS OF THE UNITED STATES. BASED ON U. S. WEATHER BUREAU RECORDS FOR 50 YEARS.

Fig. 67 — Freezing Protection For Engine Cooling Systems In U.S.A.

FILLING SYSTEM WITH ANTIFREEZE

When freezing weather is expected, the engine should either be completely drained or an antifreeze solution installed in the cooling system. Normally, flush out the cooling system (page 65) before adding antifreeze.

As soon as the danger of freezing is past, the antifreeze should be drained and replaced with clean soft water . . . plus inhibitors. This is important because neither alcohol nor permanent antifreeze will pick up heat as rapidly as water and the engine may run hot. This could cause burned valves and other problems.

NOTE: Some engines are designed to use permanent-type antifreeze in the cooling system during the whole year. In this case, follow the manufacturer's instructions. There are also a few engines which have sealed cooling systems with undiluted antifreeze as coolant, but these are not common.

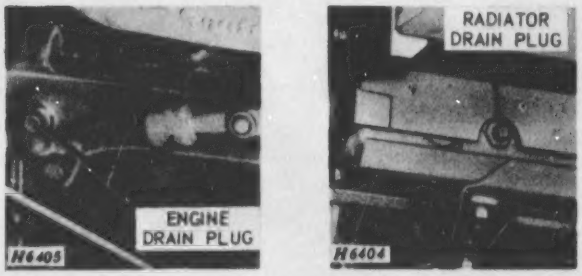


Fig. 68 — The Cooling System Usually Has At Least Two Drain Plugs

When draining any system, be sure that all drains are opened (Fig. 68). Many engines not only have a drain at the bottom of the radiator, but also one or more drains on the engine block. Some also have a drain at the engine oil cooler (if equipped). Unless all drains are opened, some coolant will be left in the system.

When putting an engine back in operation after it has been drained for freezing protection, always turn the cooling fan by hand to be sure the water pump is free. If the pump is frozen, thaw it out before starting the engine. Otherwise the pump will be damaged.

When filling the system, use a recognized brand of **new** antifreeze, containing a rust inhibitor, and clean soft water. (See Fig. 67 for instructions on freezing protection.)

After adding antifreeze, run the engine for a few minutes until it reaches normal operating temperature. This will allow the thermostat to open and will assure that the solution has circulated through the entire system for full protection against freezing.

Recheck the cooling system for leaks and condition the system with a stop-leak compound if recommended in the operator's manual.

Fig. 69 — Never Pour Cold Water Into A Hot Engine

IMPORTANT: Never pour hot water into a cold engine or cold water into a hot engine (Fig. 69). You may crack the head or the cylinder block. Do not operate the machine without water for even a few minutes.

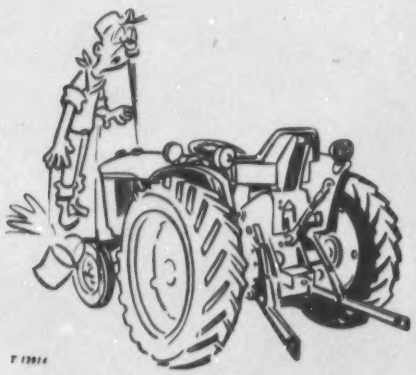


Fig. 70 — Be Careful When Removing The Radiator Pressure Cap

CAUTION: When checking the coolant level, wait until the coolant temperature is below the boiling point to remove the pressure cap (Fig. 70). Then loosen the cap only to the stop to relieve pressure before removing it completely.

Never overfill the system. A pressurized system needs space for heat expansion without overflowing at the top of the radiator. Leave from ½ to 2 inches (13 to 51 mm) of space between the radiator water level and the neck of the radiator.

WARM WEATHER CONDITIONING OF SYSTEM

Normally, antifreeze solutions should be drained in summer and replaced with clean soft water. But the important thing is to **add a coolant conditioner.** A good coolant conditioner:

1. *Softens the water*
2. *Controls corrosion*
3. *Filters the coolant*

There are few areas where tap water is soft enough for use by itself in the cooling system. Problems caused by coolant can be:

1) Deposits which impair heat transfer.

2) Corrosions of system components.

By using a coolant conditioner in the water, scale and corrosion can be kept to a minimum.

SUMMARY: PREPARING SYSTEM FOR SEASONS

WARM WEATHER OPERATION

1. Fill with soft water whenever available.
2. Add a can of coolant conditioner to inhibit rust and corrosion.
3. Add a reliable brand of radiator sealer (only if required).
4. Keep system filled to a level midway between the radiator core and bottom of filler neck. Do not overfill.

COLD WEATHER OPERATION

1. Fill with a mixture of antifreeze (with rust inhibitor) and soft water for protection against freezing to the lowest temperature anticipated.
2. Add a reliable brand of radiator sealer if required.
3. Run engine several minutes after thermostat opens to circulate coolant.
4. Recheck system for leaks.

MAINTENANCE OF COOLING SYSTEM

The cooling system has the job of absorbing about one-third of the heat energy developed by the engine. (Another third is used for power and the remainder is taken off through exhaust gases and crankcase oil.) Anything that slows down the movement of heat from the cylinders to the cooling system may cause the engine to *overheat*. This may lead to damage and expensive repairs, but it can be avoided by regular maintenance of the cooling system.

We will cover maintenance of the cooling system as follows:

- **Preventing leaks**
- **Preventing corrosion and deposits**
- **Flushing or cleaning the system**
- **Water pump and fan lubrication**
- **Stopping a hot engine**

Let's discuss each subject in detail.

PREVENTING LEAKS

Leaks in the cooling system can mean a loss of valuable antifreeze. A serious leak can cause the engine to overheat and become damaged.

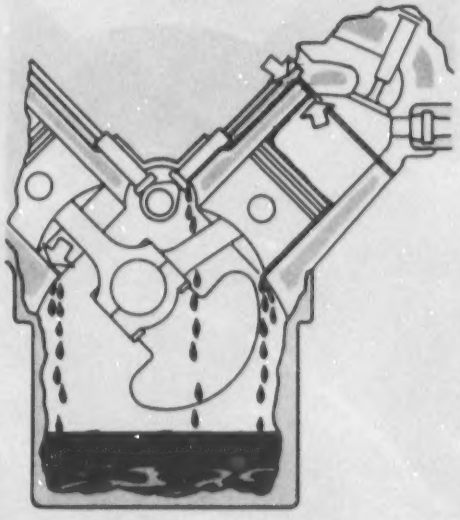


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Fig. 71 — Coolant Leaking Into The Crankcase Can Cause Lubrication Failure

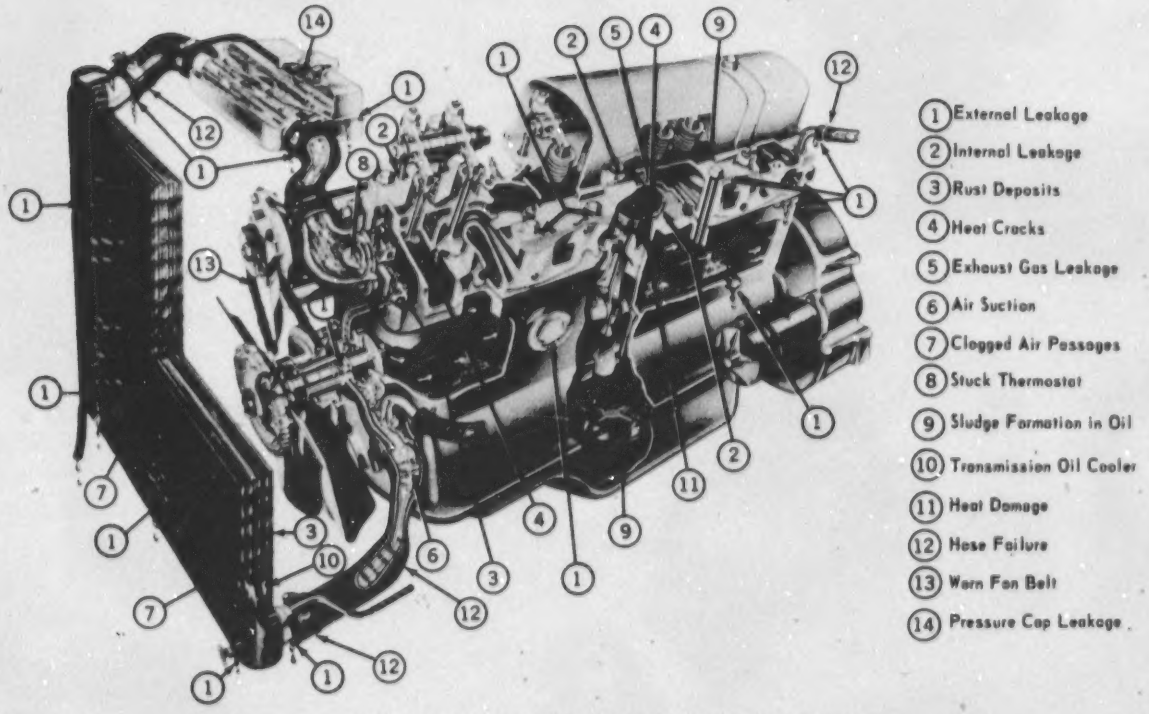

Fig. 72 — Maintenance Problems Of The Cooling System

If antifreeze solution leaks into the engine crankcase (Fig. 71), it can dilute the oil until the engine's lubrication fails. When antifreeze or water mixes with oil, it forms sludge and gum which retard lubrication and cause sticking of valves, valve lifters, or piston rings.

To prevent leakage of coolant into the crankcase, check the cylinder head joints periodically to be sure the gasket is okay and the cap screws are tightened to specifications.

Stop-Leak Products

Cooling system leaks can be caused by another of these problems: Loose cylinder head and other gasket joints, loose hose clamps, fracture of radiator solder, corroded water tubes in the radiator, and rotten hoses and gaskets.

To stop small leaks, at least temporarily, stop-leak compounds can be effective. The main problem is that they may give the serviceman a sense of false security. For example, stop-leak may prevent seepage at a hose connection through the *inner* lining, but finally the hose will rot and burst, losing coolant and overheating the engine.

Even after leaks are eliminated, stop-leak is good in the coolant to reseal old leaks and to seal any new ones before they get serious.

However, stop-leak compounds *will not* correct a leaking cylinder head gasket because of the heat and pressures.

Stop-leak compounds can lead to radiator clogging if water tubes already contain deposits which act as a strainer. If coolant level gets too low, some stop-leak ingredients may harden in the upper radiator and block it.

However, stop-leak compounds are usually recommended in the correct dosage for preventive maintenance in engines.

Before using a stop-leak, check your operator's manual. The compound must be compatible with the antifreeze and the inhibitors, and it must be installed correctly and in the right quantity.

NOTE: Some antifreezes now contain stop-leak additives, but the value of these additives should be checked with the supplier. If approved by the engine maker, no further stop-leak compound is needed in the system.

56

Air Leaks Into Cooling System

Air mixing with the coolant in the system speeds up rust and corrosion. It may also cause foaming, overheating, and overflow loss of coolant.

Air leaks into the coolant may be caused by:

- *Leak in the system*
- *Turbulence in top radiator tank*
- *Too-low coolant level*

Testing For Air Leaks In The Cooling System

If air leaks in the cooling system are suspected, the following checks can be made.

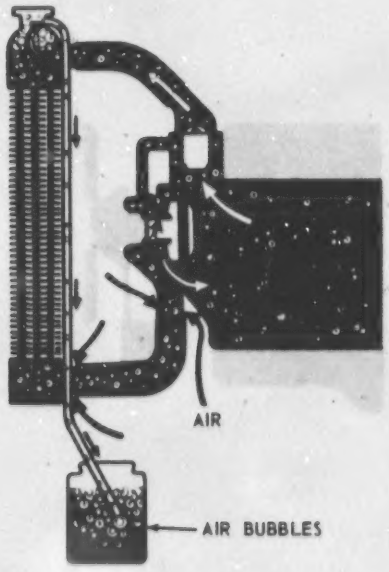

Fig. 73 — Testing For Air In Cooling System

1. Adjust coolant to correct level.

2. Replace pressure cap with a plain, air-tight cap.

3. Attach rubber tube to lower end of overflow pipe (Fig. 73). Be sure radiator cap and tube are air-tight.

4. With transmission in neutral gear, run engine at high speed until temperature gauge stops rising and remains stationary.

5. Without changing engine speed or temperature, put end of rubber tube in bottle of water.

6. Watch for a continuous stream of bubbles in the water bottle, showing that air is leaking into the cooling system.

Exhaust Gas Leaks Into Cooling System

A cracked head or a loose cylinder head joint allows hot exhaust gas to be blown into the cooling system under combustion pressures, even though the joint may be tight enough to keep liquid from leaking into the cylinder.

The cylinder head gasket itself may be burned and corroded by escaping exhaust gases.
Exhaust gases dissolved in coolant destroy the inhibitors and form acids which cause corrosion, rust and clogging.

Excess pressure may also force coolant out the overflow pipe.

TESTING FOR EXHAUST GAS LEAKAGE (BLOW-BY)

1. Warm up the engine and keep it under load.

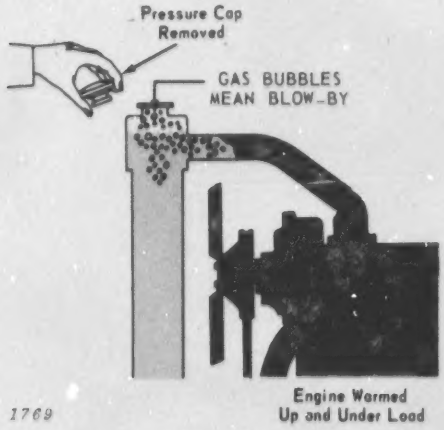

Fig. 74 — Test For Exhaust Gas Leakage (Blow-By)

2. Remove the radiator cap and look for excessive bubbles in the coolant (Fig. 74).

3. Either bubbling or an oil film on the coolant is a sign of blow-by in the engine cylinders.

NOTE: Make this test quickly, before boiling starts, since steam bubbles give misleading results.

57

PREVENTING CORROSION AND DEPOSITS

Three types of corrosion can attack the parts of the cooling system:

- **Chemical corrosion**
- **Electrolytic corrosion**
- **Erosive corrosion**

CHEMICAL CORROSION is a direct chemical reaction between the coolant and the metal parts of the system. This may be caused by acids in the coolant or various oxidizing agents. An example is the formation of rust on iron parts by the water and oxygen reacting with the metal.

ELECTROLYTIC CORROSION is a reaction between two different metals joined together, in contact with a solution which conducts electricity. This action is the same as that of a dry-cell battery which produces current by converting a metal into salt. When selecting an antifreeze, be careful that it is not a good conductor, such as a salt solution.

EROSIVE CORROSION is the mechanical abrasion from particles such as rust, scale, and sand as they circulate rapidly through the system with the coolant.

The result of corrosion on metal surfaces is that heat transfer is reduced.

Water solutions will corrode the cooling system metals unless they are protected by inhibitors added to the water during summer operation.

Good antifreeze solutions already contain rust and corrosion inhibitors. However, these inhibitors "wear out" with use. This is one reason why even permanent antifreezes are recommended for only one or two seasons in a system.

Preventing Cooling System Deposits

Lime and mineral deposits can be reduced by using soft water — rain water is best.

Mineral deposits form rapidly at hot spots in the engine (Fig. 75).

Because heat transfer is reduced, deposits can lead to overheating, knocks, and eventually engine damage.

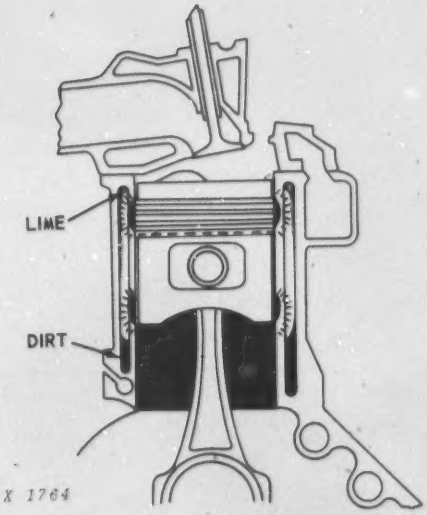

Fig. 75 — Mineral Deposits

FLUSHING OR CLEANING THE SYSTEM

Always flush the system before installing antifreeze. Rust and other deposits in the system can shorten inhibitor life (and also reduce cooling efficiency). When draining the system, if the coolant contains rust and scale, *clean the system with an acid-base cleaner*. Be sure to follow the manufacturer's instructions.

It is also important to follow the engine maker's instructions when flushing or cleaning their system. For example, some alkaline cleaners can corrode aluminum engines or radiators.

For heavy deposits in the system, more drastic cleaning with an acid-base cleaner may be needed. The solution should remain in the system for two to three hours at operating temperatures and then be drained. To neutralize the acid, the system must then be flushed with water, to which a can of lye has been added. After running the engine for a while, the lye water should be drained and the system *flushed again* to remove all traces of the lye. water. *This is important.*

Flushing The System

Incomplete flushing, such as hosing out the radiator, closes the thermostat and prevents thorough flushing of the engine water jacket.

For complete flushing, take the following steps:

1. Fill the system completely with fresh water.

2. Run the engine long enough to open the thermostat (or remove the thermostat).

3. Open all drain plugs to drain the system completely. (Most systems have at least two drains. See Fig. 66.)

Clean out the overflow pipe and remove insects and dirt from radiator air passages, radiator grille and screens.

Also check the thermostat, radiator pressure cap, and the cap seat for dirt or corrosion.

WATER PUMP AND FAN LUBRICATION

In most engines, the water pump is driven by the same shaft as the cooling fan. Usually, the shaft bearings are factory-lubricated and sealed and require no further lubrication. However, some fan and water pump units must be lubricated periodically through a grease fitting (often with a special grease). Here it is important that coolant does not leak into the bearings (Fig. 76).

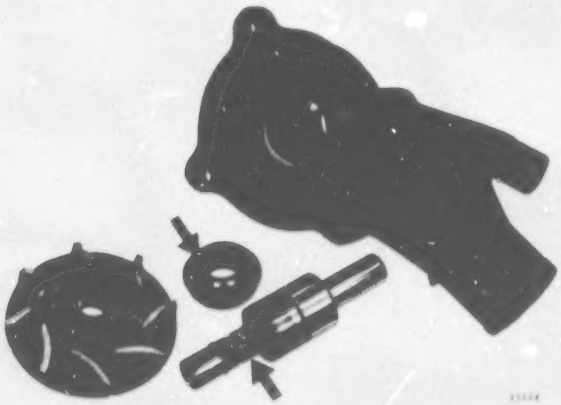

Fig. 76 — Water Pump With Corroded Bearing And Shaft

Other water pumps are lubricated by additives in the coolant. For this reason, most permanent antifreezes already contain a water pump lubricant; so do most inhibitors that are used with plain water. In this case, it is doubly important to *change the coolant or add inhibitors at regular intervals.* Check the operator's manual for the exact intervals and procedures.

STOPPING A HOT ENGINE

When an engine has been working hard, the pistons and other parts are very hot and should be allowed to cool gradually to prevent seizing and permanent damage.

Allow a hot engine to idle for a few minutes before shutting it down.

This will prevent the engine from running after the ignition is turned off. Above all, it will keep the hot piston and other parts from stewing and coking in their own oil films, producing deposits. Another problem is that a red-hot valve, open when the engine stops, may warp and later burn.

SUMMARY: COOLANTS

Here is a summary to the major facts about coolants:

1. Water is the universal coolant — plentiful, cheap, harmless, absorbs heat, circulates freely. But it will freeze, it can evaporate and it will also corrode metals.

2. Water needs added **inhibitors** *to prevent corrosion and* **antifreezes** *to prevent freezing.*

3. Use clean soft water in the cooling system — rain water is best.

4. "Permanent" only means that an antifreeze will not readily boil away; the inhibitors will still "wear out" in a season or two.

5. Alcohol antifreezes boil at 180°F (82°C), while ethylene glycol (permanent) antifreezes do not boil until 223°F (106°C). Compare water, which boils at 212°F (100°C).

6. Never overfill the cooling system. It needs room for heat expansion.

7. **Two precautions:** *a) Never pour cold water in a hot engine, or vice versa. b) Never remove the pressure cap all at once on a hot engine.*

8. Watch for all kinds of leaks: Coolant out of system, coolant into crankcase, and air and exhaust leaks into coolant.

9. Corrosion of metal surfaces in the system reduce heat transfer and cause overheating. Use inhibitors both summer and winter (in most antifreezes).

10. Flush the system before installing antifreezes. If rusted or limed up, clean the system with an acid-base cleaner, then neutralize and flush it.

11. Check water pump and fan for proper lubrication. Some are greased; others must be lubricated by the coolant.

12. Allow a hot engine to idle for a few minutes before stopping it.

TEST YOURSELF

QUESTIONS

1. How much engine heat is actually used to produce power?

   a. 35%

   b. 60%

   c. 75%

2. When the engine coolant is cold, is the thermostat open or closed?

3. True or false? "Clean soft water is all the coolant needed for summer operation."

4. Which is a "permanent" antifreeze?

   a. Ethylene glycol base

   b. Alcohol base

5. Identify the liquid which boils at each of the temperatures below:

   a. 180°F (82°C).....

   b. 212°F (100°C) .....

   c. 223°F (106°C) .....

6. Why is a "permanent" antifreeze only good for one or two seasons?

7. What happens if you overfill a pressurized cooling system?

8. True or false? "Always shut down a hot engine as quickly as possible to prevent afterrunning."

(Answers — see next page.)

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ANSWERS TO FUELS QUESTIONS (from page 25)

1. a-2; b-3; c-1.

2. The spark ignites the fuel-air mixture next to the plug which builds up pressure and "explodes" the unburned fuel in the remainder of the cylinder.

3. a-1-B; b-2-A.

4. Winter gasoline blends are more volatile.

5. False. Knocking in diesels is caused when fuel ignites too *slowly*. The fuel should ignite almost spontaneously; this is different from gasoline engines.

6. The diesel fuel with a 60 cetane rating is more volatile.

7. White — because it reflects heat and reduces fuel loss by evaporation.

8. b – 40 ft. (12 m).

9. A – 80%.

ANSWERS TO LUBRICANTS QUESTIONS (from page 54)

1. SAE 30 is the thicker oil.

2. CD oils are used in machines for more severe service.

3. (Any three of the following.) Anti-corrosion additive, oxidation inhibitor additive, anti-rust additive, viscosity index improver, pour point depressant additive, extreme pressure additive, detergent additive, foam inhibitor additive.

4. False. Oil loses its good qualities as it absorbs contaminants and its additives are depleted.

5. The most common case is unburned fuel entering the crankcase.

6. True. The API standards for oils do not define the additive content.

7. False. For example, in a diesel engine, oil should turn black with use.

8. Yes. The different SAE numbers are only used to avoid confusion between different types of oils.

9. All four are vital qualities of a hydraulic fluid.

ANSWERS TO COOLANTS QUESTIONS (from page 67)

1. a. 35%

2. Closed. (To allow coolant to circulate in the engine only for faster warm-up.)

3. False. A corrosion inhibitor is needed even with a clean soft water.

4. a. Ethylene glycol base.

5. a. Alcohol-base antifreeze
   b. Plain water
   c. Ethylene glycol-base (permanent) antifreeze

6. Because the inhibitors "wear out."

7. As heat expands the coolant, it overflows and some is lost.

8. False. Allow a hot engine to idle for a few minutes to cool it gradually.

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